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ERRATA

p. 2	Résumé français (l'auteur ne l'a vu pas avant publication). Par. 2, dernière ligne: remplacez "d'espèces" par "des individus". Par. 4, lignes 3-4: éliminez "sur l'île". Par. 5, dernière ligne: éliminez "là où se trouvait le lac".
p. 24	Vagrants. Line 11, "west" should be "east".
p. 30	Account of species. Line 1, "325" should be "324".
Table III	Following dates or numbers should be: Spotted Sandpiper, SPRING MIGRATION, First Seen, median - 23 May Ruby-crowned Kinglet, FALL MIGRATION, Number of years - 11 Water Pipit, SPRING MIGRATION, Last Seen, median - 8 June Cedar Waxwing, SPRING MIGRATION, Last Seen, latest - 29 June Red-winged Blackbird, SPRING MIGRATION, Last Seen, latest - 24 June Brown-headed Cowbird, SPRING MIGRATION, First Seen, median - 11 Apr. Swamp Sparrow, FALL MIGRATION, First Seen, median - 14 Sept.
Table IV	Yellow-billed Cuckoo, Add "P" to Authentication column.

The Birds of Sable Island, Nova Scotia

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THE BIRDS OF SABLE ISLAND, NOVA SCOTIA

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ABSTRACT

A total of 324 species of birds, 236 authenticated by specimens or photographs, are reported from Sable Island, a treeless sandbar 150 km from the nearest mainland of Nova Scotia. Historical records are reviewed, especially the underappreciated collections and observations by James and Richard Bouteillier between 1894 and 1910. Extensive records have been kept since 1963, including quantitative daily lists of birds during 1967-1979. Research on the Ipswich Sparrow, Least Sandpiper, *Larus* gulls, and shorebird migration, is reviewed briefly.

Twenty-five species nest or have nested on the island. Almost all the species that breed in Nova Scotia, or are normal migrants or eruptives to the province, except for a few mostly sedentary or rare species, have occurred on the island. For the period 1967-1979, extreme and median migration dates, and estimated numbers of occurrences and individuals, are given for all species except seabirds and year-round residents. Landbird migrants, about 6 times more common in autumn than in spring, are not as common as on islands nearer the Nova Scotian mainland, where about 5 times as many have been listed on comparable days.

Eighty-five species defined as vagrants in the province have been reported from the island, most based on specimens or photographs, or on well-documented sightings. These include 2 first records for North America, 4 for Canada, and 24 for Nova Scotia. In comparison with other localities in eastern North America, the proportion of landbird vagrants from more remote ranges is higher on Sable Island.

The island has also produced many late and early provincial records of migrants, including some totally unseasonable ones. A substantial amount of summer wandering by presumed nonbreeders is evident. A number of boreal and arctic-subarctic species have occurred during summer. Winter appearances by "half-hardy" species imply a sustained capacity for migratory escape from deteriorating conditions.

Extensive records from the late 19th and early 20th centuries allow assessment of historical changes. Herons, terns, and shorebirds have changed in abundance over their wider ranges. Wintering waterfowl and some breeding species have declined because of the virtual disappearance of Wallace Lake, a once-extensive lagoon. Populations of some of the most abundant vagrants today, not reported in earlier years, may have responded to proliferating second-growth habitats.

RESUMÉ

On signale 324 espèces d'oiseaux sur l'Ile-de-Sable, un banc de sable dénudé situé à 150 km du point le plus rapproché de la Nouvelle-Ecosse; de ce nombre, 236 espèces ont été établies par des spécimens ou par des photographies. On examine aussi des documents historiques dont les collections et les observations sous-estimées faites par James et Richard Bouteillier entre 1894 et 1910. Depuis 1963 on a accumulé des notes d'observation considérables dont des listes journalières quantitatives des espèces observées durant la période allant de 1967 à 1979. On critique aussi des recherches sur le Pinson d'Ipswich, la Maubèche Minime, les goélands du genre *Larus*, et la migration des oiseaux côtiers.

Vingt-cinq espèces nichent sur l'île ou l'ont déjà fait. Presque toutes les espèces qui se reproduisent en Nouvelle-Ecosse, qui y migrent normalement ou qui y sont irruptives ont été observées sur l'île, à l'exception de quelques espèces sédentaires ou rares. Pour toutes les espèces, sauf les oiseaux de mer et ceux présents à l'année longue, on donne les dates de migration les plus hâtives et les plus tardives enregistrées ainsi que la médiane de ces dates. On donne aussi pour ces espèces une estimation du nombre de fois qu'elles sont venues sur l'île et du nombre d'individus impliqués. Les espèces migratrices continentales, environ 6 fois plus communes en automne qu'au printemps, ne sont pas aussi communes sur l'Ile-de-Sable que sur des îles plus rapprochées de la Nouvelle-Ecosse, îles où l'on dénombre environ 5 fois plus d'espèces que sur l'Ile de Sable au cours de jours comparables.

On a signalé sur lîle 85 espèces définies comme errantes dans la province; l'identité de la plupart de ces espèces est basée sur des examens de spécimens, des photographies ou des observations bien documentées. Ces rapports incluent 2 premières pour l'Amérique du Nord, 4 pour le Canada et 24 pour la Nouvelle-Ecosse. La proportion d'oiseaux continentaux errants venant d'habitats plus éloignés est plus grande sur l'Ile de Sable qu'à tout autre endroit de l'est de l'Amérique du Nord.

Des migrations les plus hâtives et des plus tardives enregistrées dans la province, plusieurs ont eu lieu sur l'île, dont certaines complètement hors-saison. En été il se produit un vagabondage important de la part d'espèces qui, présumément, ne se reproduisent pas sur l'île. Un certain nombre d'espèces boréales et arctiques-subarctiques ont été rencontrées en été. L'apparition en hiver d'espèces "semi-résistantes" implique le maintien de la capacité d'émigrer pour échapper à la détérioration des conditions de vie.

Une documentation considérable dantant de la fin du 19e siècle et du début du 20e siècle permet d'évaluer les changements de population dans le temps. Les hérons, les sternes et les oiseaux côtiers ont vu se modifier leur abondance dans leur habitat étendu. Les oiseaux aquatiques qui hivernent sur l'île, et quelques espèces qui n'y viennent que pour se reproduire, ont décliné à cause de la disparition du lac Wallace, un lagon jadis très important. Les populations de certaines espèces errantes les plus importantes de nos jours et autrefois inconnues sur l'île, peuvent s'être développées en réponse à la prolifération de nouveaux habitats là où se trouvait le lac.

Introduction

Sable Island (Fig 1) has long been a theatre of human history, and today is a focus of economic hope. Yet it also has a rich natural history, somewhat diminished since the first human settlement almost 400 years ago. The famous horses, the seals and the Ipswich Sparrow are all well-known inhabitants, and a surprising amount of study has been made of the island's plants and smaller forms of animal life. This is the third study titled " . . . birds of Sable Island . . . ". The first (Saunders 1903) did not fulfill its title. The second (McLaren & Bell 1972) was a preliminary account of records made between 1963 and 1971, and is now out of print.

A much-travelled colleague has remarked that he has been in places more beautiful than Sable Island, but has *seen* more beauty there than anywhere else. The expansive seascapes and dunescapes, magnificent, yet "dreary" to some 19th century writers, soon force one's attention to the smaller scale. To me, the birds are an integral part of the island's beauty and, with so many of them from afar, they bring a larger sense of time and space to one's visits there. Amassing and analyzing bird records from the island has been a pleasant distraction since my first visit there in 1967. Others have been involved in, and sometimes cajoled into this labor. I thank them in the Acknowledgements, but I hope they find more satisfaction in seeing their efforts used.

Sable Island is difficult and expensive to visit (government permission must be obtained to stay on the island, and is granted generally only to those who have work to do there). Those who live or visit there may find this a helpful guide, and I hope that they can continue to supply bird reports in the future. Serious students of birds may find the data on occurrences and migrations of use in their own faunistic or comparative studies. Those who simply enjoy birds may find this account a means of visiting, in the mind's eye, what must surely be one of the most exciting places in North America for birdwatching.

Early Records of Birds

The first descriptions of the general character of Sable Island, as in Champlain's *Voyages* and Governor Winthrop's *History of New England,* mention animals of obvious exploitability, such as seals, foxes, and cattle, but not birds (see Patterson 1894; St. John 1921, for these and other early references to the island). Andrew Le Mercier's 1753 description of the island, by which he hoped to sell it, states with advertising hyperbole that the "Air [abounds] with fowl, and especially with Black Ducks, so as to make money with their feathers" (St. John 1921). Des Barres' (1777) account accompanying his detailed survey of the island mentions "ducks, snipes, and other birds." This interest in the more useful avifauna prevailed into the 19th century in various reports (in Nova Scotia Archives) to the Nova Scotian government during and after the placement of lifesaving facilities on the island. Governor Wentworth's plea in 1800 for such facilities mentions "the vast quantities of seabirds" there. Captain Jones Fawson, who took first Superintendent James Morris with his assistants and equipment to the island in October 1801, reported to Wentworth that "the pond . . . is frequented by blue winged ducks [i.e., Black Ducks] and other wild fowl in abundance." However, Morris was less enthusiastic after 6 months' experience, for he wrote in his first report on 29 March 1802: "I never saw wild fowl so scarce in any part of America near the ocean as at this Island we have only killed about 40—tho often seek after them." This may have been exaggeration of another sort, in an effort to gain more sustenance for the new enterprise.

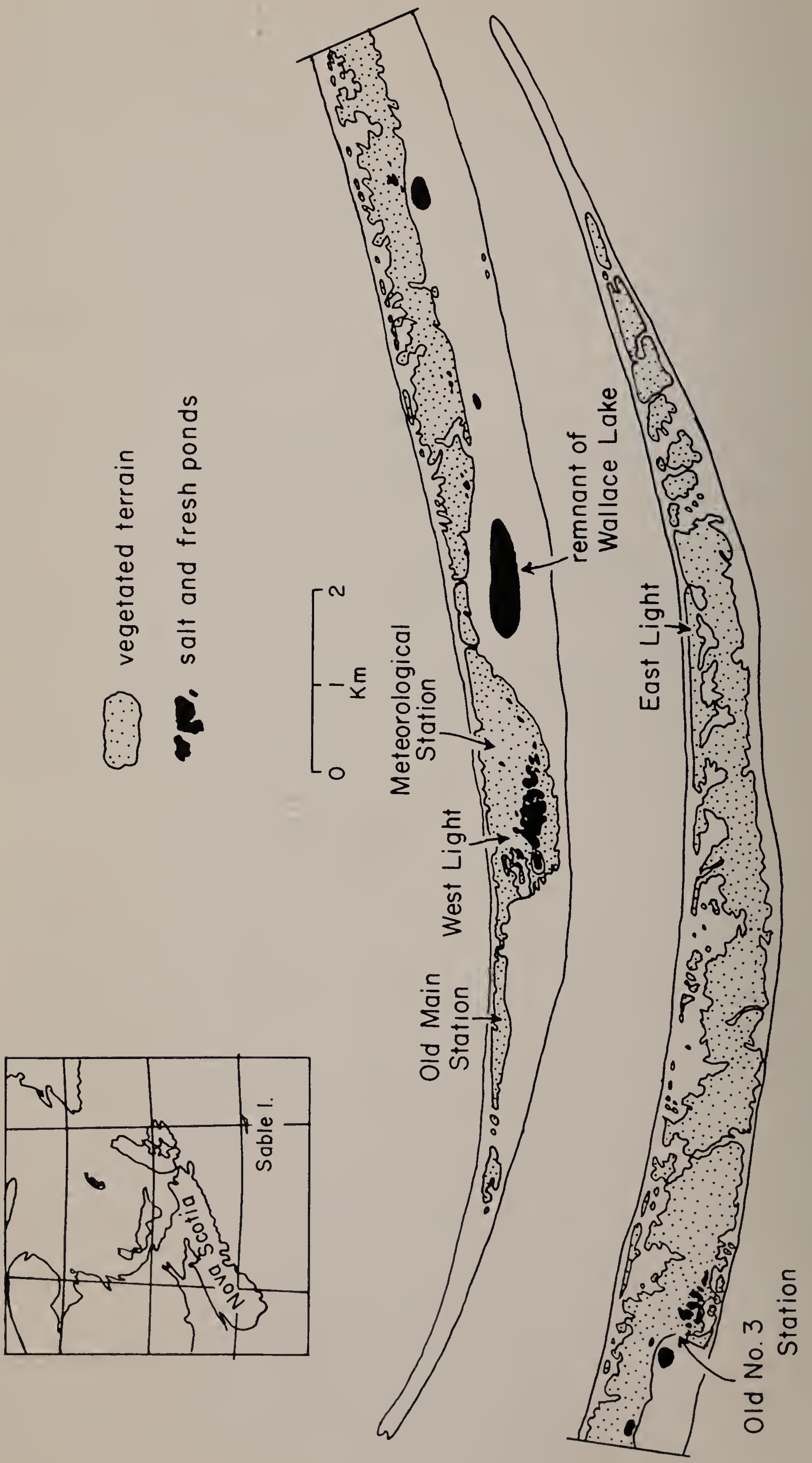

Fig 1 Sable Island, with place names mentioned in the text.

In the laconic entries in the diaries of successive 19th century superintendents of the island (in Nova Scotia Archives) there are occasional references to hunting of waterfowl and shorebirds, gathering of eggs, to arrival dates of terns (as a mark of season), and to Snowy Owls, which seemed sufficiently spectacular to command attention. Perhaps the most interesting bird reference is in a letter by Superintendent Edward Hodgson dated 30 September 1810: "We tried to raise some Oats, and had a very good appearance of a good crop but unfortunately a small bird we call the grey bird Destroyed the whole." This was clearly an early reference to the Ipswich Sparrow—one of the island's many dangers! A later hint of a broader interest in the natural history of this bird is found in the sets of eggs collected by J.P. Dodd, a resident of the island, in 1862, and subsequently attributed to the Ipswich Sparrow (Ridgway 1884).

Some published accounts of 19th century life on the island give a bit more information on birds, with the usual emphasis on game species. Captain J.A. Farquhar, whose father was posted to the island in the mid-1800's, writes (Martin 1946) that "in their season the curlew, plover, bluewing duck and snipe came by the thousand." After describing how once he killed 19 curlew with a single shot, he laments that on a visit to his old home in 1913 "there were very few curlew and plover compared with seventy years ago." Another sporting visitor to the island in the summer of 1866 was sufficiently interested to enumerate several species of shorebirds, ducks, and other species, complete with scientific names (Vieth 1907).

The first explicit references to the natural history of birds on the island during this era are in the small book by Dr. J.P. Gilpin (1858) based on his visit to the island in summer 1854. Gilpin makes statements about the breeding ducks, shorebirds, and terns, describes an earlier summer visit by a Snowy Owl, mentions "a small brown sparrow", and adds to the previous lists "a few Hawks, a Robin or two, a wild Pidgeon Plover, and some large, black-backed Gulls, . . . Shearwaters and Mother Carey's Chickens . . ." However, he subsequently (Gilpin 1880; 1881; 1882) included only a trickle of references to the island's birds in his series on the birds of Nova Scotia (Barnacle Goose—see under Snow Goose in the present account, Black Duck, Snowy Owl, and Upland Plover). The terse list of Downs (1888) refers only to the Razorbill, terns, Red Phalarope, and Snowy Owl from the island. Piers (1892; 1894; 1897) ignores these previous records and adds no more in his accounts of Nova Scotian birds.

Sable Island was, alas, not visited by any of the many naturalists who were exploring the reaches of the continent during the late 18th and early 19th centuries. Oddly, it is in the (literally) passing observations by Mrs. John Graves Simcoe (Robertson 1934) that we find the earliest hint of the real flavor of Sable Island ornithology. Mrs. Simcoe, coming to the New World with her husband, soon-to-be Lieutenant-Governor of Upper Canada, described in her diary the uneasiness aboard ship as it neared Sable Island during hard weather between 25 and 28 October 1771. However, her strong interest in natural history came to the fore, and she was able to note "a bird like a linnet and a crossbill" aboard ship on 26 October and next day described the capture of "a beautiful owl, olive colour, with white spots and black about his face . . . not larger than a thrush and not wild; also a bird the size of a lark." This scattering of landbirds far out to sea (including what may have been an early record of the rare Boreal Owl) is a feature of the ornithology of Sable Island that remained almost undocumented until another century had passed.

The Ornithological Bouteilliers and their Naturalist Visitors

Beginning in 1894, there was a period of intense study of the island's birds. This was occasioned in part by the visits of some well-known naturalists of the day, but most of the activity was by some children of Robert J. Bouteillier, the island's Superintendent between 1884-1912. Bouteillier himself was a man of great vigor, intelligence, and organizational ability, of whose talents and hospitality have been widely written by visitors to the island during those days.

Some time after the discovery of the "Ipswich Sparrow" by Maynard (1872), and following upon indications that it nested on Sable Island (Ridgway 1884; Merriam 1884), Jonathan Dwight, Jr., of New York City visited the island between 28 May and 14 June 1894 in order to study the bird on its nesting grounds (Dwight 1895). The visit by this well-known American ornithologist had a profound influence on the 3 youngest Bouteilliers: Sara Beatrice or "Trixie" (1879-1978), Richard S. or "Dick" (1881-1928) and James W. McL. or "Jim" (1885-1971). In a taped interview a few years before her death, Trixie Bouteillier describes how Dwight taught them to make bird skins and was able, after so many years, to refer to some of the island's birds by the Latin names used in Dwight's day. The boys (Fig 2) became especially serious, and James retained his interest through his later years at Sault Ste. Marie, Ontario (R.S. Bouteillier, in litt.).

Fig 2 Pioneer students of the birds of Sable Island, James (left) and Richard (middle) Bouteillier, with a companion, about to mount an attack on the island's introduced foxes. (Photo: ca. 1895, courtesy Robert S. Bouteillier.)

An important result of Dwight's visit was a series of bird skins from the island now in the American Museum of Natural History (AMNH) and the Science Museum, Springfield, Massachusetts (SMS). Some were taken by Dwight himself (90 catalogued in AMNH, 9 in SMS), but a larger number (177 in AMNH, 37 in SMS) are dated subsequently to his visit, and were clearly sent to him by the Bouteilliers; there is direct evidence of this on some labels. The earliest of these is a Lincoln's Sparrow dated 30 June 1894, and the latest are 3 Whimbrels taken 6 September 1910. The collection includes a substantial 107 species of birds. Others may be scattered elsewhere, for Dwight's correspondence at the Museum of Comparative Zoology (MCZ) at Harvard University, largely American Ornithologists Union (AOU) business, has references to the selling and trading of specimens, including eggs of the Ipswich Sparrow. A Long-tailed Jaeger was more recently sent from the AMNH to the Australian Museum, Sydney. I have been unable to trace other possible dispositions of Dwight's Sable Island material from known, but limited, correspondence at the Museum of Comparative Zoology and at the Academy of Natural Sciences, Philadelphia.

Between 29 July and 3 August 1898 the island received the polymathic Alexander Graham Bell and a party of 5, including his wife and daughter. The visit is recorded by J.R.T. Atwater in the *Baddeck Telephone* (Victoria Co. Archives, Nova Scotia) for 31 August 1898. Atwater gives an account of the people and natural history of the island, mentioning the common birds.

It is a measure of the esteem felt by the Bouteilliers for Bell and Dwight that both were included among 5 who received messages upon the opening of the wireless station on the island, on 27 June 1905 (Nova Scotia Archives).

John Macoun of the Geological Survey of Canada was the next bona fide naturalist to visit the island, for 5 weeks during July-August 1899. He made general observations, collected plants, but mentioned only the Ipswich Sparrows and the "Canada" (i.e., Red-breasted) Nuthatch in his brief report (Macoun 1899). However, he was obviously impressed by and wished to impress the young people, as shown by his Victorian homily in the Bouteilliers' visitors' book (R.S. Bouteillier, in litt.): "To the young people I may, as a teacher, say go on as you are doing—observing and thinking and although shut out from the world and all its vanities and follies you are not shut out from nature which if taken aright is the best teacher and the one that when accepted as a guide gives the purest happiness." Unfortunately Macoun's later somewhat careless use of the Bouteilliers' bird records (see below) did not match these sentiments.

In 1901 a massive and ultimately futile effort was made to plant trees on the island, under the direction of William Saunders, Director of the Dominion Experimental Farms system. St. John (1921) gives an accessible summary of this operation and its outcome. Accompanying Saunders was his son William Edwin, an active avocational ornithologist from London, Ontario. Based on his short stay, during 16-23 May 1901, W.E. Saunders (1902a) wrote an account of the birds (the same appeared in the London, Ontario *Advertiser* of 20 July 1901) and 2 short notes on the Ipswich Sparrow (Saunders 1902b; 1905), none of which added much to observations made by Dwight (1895). However, Saunders may have had an important role in initiating the Bouteillier boys in the keeping of seasonal lists in ensuing years (see below).

A series of notes on birds seen on the island by the Bouteilliers appeared at the beginning of the century in the *Ottawa Naturalist* (Bouteillier 1901; 1905; 1906; 1908a; 1908b). An indication that a list for 1902 had been circulated, although not published, came from 2 sources: 1) the minutes of 6 February 1903 of the Ornithological Section of the Entomological Society of Ontario (Judd 1972) state

Table I Annual lists, published and unpublished, made by Richard W. and James W. McL. Bouteillier on Sable Island, 1901-1908.

Period covered	Author of original list	MS on file	Published version Date	Published version Stated Author
3 Aug.—4 Nov. 1901	Richard	no	1901	Richard Boutelier
28 Mar.—30 Nov. 1902	James	yes	—	
2 Jan.—25 Dec. 1903	James	yes	—	
21 Jan.—20 Aug. 1904	James	yes	1905	James Bouteiller
23 Apr. 1905—6 Jan. 1906	James(?)	no	1906	James Bouteiller
28 Mar. 1906—1 Jan. 1907	Richard	yes	1908	James Bouteiler
20 Jan.—16 Nov. 1907	Richard	yes	1908	James Bouteiller
20 Apr.—31 Dec. 1908	Richard	yes	—	

that "an extended report on migrations on Sable Island, by Mr. James Boutilier (*sic*), was examined and discussed"; 2) Macoun and Macoun (1909) include several 1902 records. Through Dr. R.W. Tufts (in verb.) I discovered that handwritten lists, which he referred to in preparing his *Birds of Nova Scotia* (Tufts 1973), were on file at the Nova Scotia Museum. These lists for 6 years include 3 unpublished ones (Table I). Altogether, 149 species are included on the lists (113 on the published ones). In addition, there is an account of an interview on 10 June 1902 with Robert Bouteillier in the hand of Harry Piers, then Curator of the Provincial Museum, Halifax, describing the status of 104 species, including 24 not on the seasonal lists. The birds are mostly listed on the Piers manuscript by AOU number, rather than by name, and the list has evidently, and unfortunately, been truncated by the loss of one or more pages, as it ends at AOU number 621 (Northern Shrike).

The genesis of these annual lists is somewhat uncertain. The first is not on file in the Nova Scotia Museum, and it follows upon the spring visit by W.E. Saunders (see above). According to the minutes of the Ornithological Section of the Entomological Society of Ontario (Judd 1972), of a meeting held at Saunders' home on 13 December 1901, "a letter with records of autumn migration from Sable Island was read and elicited much discussion." It is probable this letter had been sent to Saunders and was the basis for the published list (Bouteillier 1901). The subsequent published lists are more comprehensive and the unpublished ones are organized in a standard way, with column headings ("Name of species; When first seen; When did it become common; When last seen; Does it breed in your locality; Abundance; Remarks") in the hand of Harry Piers. The columns have then been filled by the Bouteilliers. Furthermore, there are similar lists from the same era (1902 et seq.) on file at the Nova Scotia Museum. Clearly the lists from Sable Island and elsewhere were part of an enterprise by Harry Piers. It is not certain if their publication, beginning in 1904, was expedited through Piers or through copies made available to Saunders.

The annual lists, together with the Piers manuscript of the interview with Richard Bouteillier, are a remarkable and valuable contribution, and were obviously of sufficient interest to be partly published at the time. However, the published versions of the lists and other references to them contain numerous errors and infelicities that should be pointed out or corrected. First, there has been a pervasive tendency in references to the Bouteilliers to misspell their name. The holographic version used by all members of the family was as I give it, and this spelling is still used by descendents today (R.S. Bouteillier, in litt.). Dwight (1895) and Saunders (1902a) used "Boutilier", Macoun (1899) and Macoun and Macoun (1909) used "Boutelier"; and the published lists give 3 variant spellings, none correct (see Table I). Another series of errors is in the attribution of some lists to the wrong Bouteillier brother in the published versions (Table I). In fact, the lists were begun by Richard, the older brother, and continued in 1902-1905 by James, as Richard was off the island between 4 June 1902 and 10 January 1905. In the absence of the original manuscript, the authorship of the published 1905 list is uncertain, although both brothers made observations recorded on the 1906 list (see below: case of the Henslow's Sparrows). However, James left the island for employment as a wireless operator between 14 August 1906 and 1 January 1910, and Richard kept the lists for 1906-1908, leaving the island himself on 26 March 1909. The errors of spelling and attribution on the published lists are all the more remarkable, as the authors' clearly handwritten names appear on all the original manuscripts. The published lists also have a few omissions and some errors in names, numbers, and dates of birds seen. I correct some of the more serious errors in the Account of Species. There are many more errors in the references to the birds of Sable Island by Macoun and Macoun (1909), almost all carelessly extracted from the unpublished 1902 list and subsequent published ones; it is best to ignore their secondhand reports.

Generally speaking it has been the fate of the Bouteilliers' records to be ignored in more recent accounts of the birds of the regions that include Sable Island. For example, Bent (1921; 1922; 1927) included records from Dwight's publications, but not those of the Bouteilliers. Possibly there was concern about the validity of some of the more unusual records. Piers annotated some of the Bouteilliers' lists with queries, and also wrote to them for further information on some records. A letter from James Bouteillier to Piers on 9 May 1903 (on file, Nova Scotia Museum) states that he had sent 3 skins of the Ipswich Sparrow and then, referring to the 1902 list, says: "I am absolutely certain of the identification of the Stilt Sandpiper, Mockingbird, Dickcissel, Yellowheaded Blackbird, and Orchard Oriole. I had all in hand and skinned some of them which I sent to a friend in the States". Some are indeed in Dwight (1903), although the Orchard Oriole (see Account of Species) remains in doubt. In a letter to Piers on 18 August 1907, concerning the published 1906 list (Boutillier 1908a), Richard Bouteillier writes: "I regret . . . we have not a specimen of Henslow's Sparrow . . . . My brother James, who is now on the mainland, recorded them, therefore I do not know much about the matter . . . . " Piers' marginal comment was: "probably not Henslow's." Macoun and Macoun (1909) echo this conclusion on the Henslow's Sparrows. Correspondence between Piers and P.A. Taverner, then Dominion Ornithologist, in 1920 (on file, Nova Scotia Museum) suggests that other records by association might be suspect. Tufts (1973) made only limited use of the published and unpublished material.

Certainly individual records on the Bouteilliers' lists can be questioned, and I consider a number of these records in the Account of Species. However, in view of the large number of unusual species that have been recorded in recent years, many of them fully authenticated, similar sight records on the Bouteilliers' lists certainly should not be rejected out of hand. There remain, of course, the extensive records of more commonplace birds, from a period of 8 years, and the many specimens taken over a period of 16 years. I make full use of these hitherto underappreciated contributions.

Scattered Records of Birds, 1911-1953

After the departure of the Bouteilliers, there was a lengthy period when, as far as is known, no systematic records of birds were kept by the island's inhabitants, and there were only occasional visits from naturalists and scientists with ornithological interests.

Dr. H.T. Güssow of the Central Experimental Farm, Ottawa, visited in late August and early September 1911, and collected plants extensively, but evidently did not publish observations. Harold St. John visited the island in 1913, but his excellent account of the character, history, and botany of the island (St. John 1921) includes no original observations on birds.

Rosebrugh (1932) includes some casual observations on the birds based on his residence on the island during 1916.

I have been unable to find any records for the period between the World Wars, but in 1945, Dr. W.W. Judd landed briefly on the island and made hasty observations on natural history, sighting what he retrospectively believed was an Ipswich Sparrow (Judd 1948).

John J. Elliot of New York visited the island between 30 July and 3 August to see firsthand the breeding Ipswich Sparrow, as part of his preparation in writing an account of the bird for Bent's *Life Histories* (Elliot 1968). His earlier account of the bird (Elliot 1956) includes some observations on other species on the island, as does a letter dated 11 December 1948 to Dr. H.F. Lewis, Chief of the Dominion Wildlife Service (letter on file, Canadian Wildlife Service, Ottawa). The letter, incidentally, is of interest in having a sensible Long Islander's prescriptions for restoration of damaged dunes on Sable Island, using approaches that have come to be realized in the last few years. Neither account contains any reference to one most unusual species that Elliot is said to have seen on the island (see Roseate Spoonbill in the Account of Species).

John Erskine of Wolfville, Nova Scotia, an accomplished naturalist, made trips to the island in summer 1952 (no dates given) and on 28-30 August 1953. His account of the ecology of the island, with emphasis on its botany (Erskine 1953) includes a number of bird sightings.

Recent Records of Birds

The Account of Species in this monograph is based largely on extensive records of birds begun in June 1963, with the arrival of Christel Bell, whose husband Norman Bell became employed on the island. The Bells observed birds largely in the vicinity of their house near West Light, perhaps the best area for a diversity of migrants and vagrants. Until the end of 1966, Mrs. Bell recorded all of the less common species, but only the first seasonal sightings of more common ones. From the beginning of 1967 until their departure in March 1970 (except for absences 19 August - 11 October 1968 and 24-30 September 1969) she kept daily records of numbers of individuals of all species seen. Her records, together with other recent ones through 1971 (see below) were the basis for an earlier, preliminary account of birds on the island (McLaren & Bell 1972), and are still the most seasonally sustained and comprehensive data available.

Beginning with a brief visit in June 1967 to census the Ipswich Sparrow (McLaren 1968), extensive research on the island's wildlife and environments has been carried out by myself and colleagues and students. Ecological research on certain species of birds will be summarized in the next section. In addition, some of us have also kept records of birds seen in the course of our work, and several have made daily lists of all species seen. Between 1968 and 1979, at least 1 and often several observers were present on the island during spring and summer (usually from early or mid-May to the end of August or early September) and often at other times of year as well. In the course of their work, students lived at both East Light and West Light, and often ranged widely over the island. Some of these observers were active photographers who together have thus authenticated many species of birds on the island. Those who contributed are enumerated in the Acknowledgements and some are identified as authorities for more unusual sightings in the Account of Species.

Beginning in May 1974 and until the end of 1979, regular lists have been sent to me by Alban A. Richard, a government employee on the island. These were either daily counts of birds seen or were summaries of estimated numbers seen during portions of seasons. Most of his observing was done near West Light or around the Meteorological Station. His records are especially valuable in supplying early and late records during seasons, when no other observers were on the island.

Other visitors and residents on the island have supplied scattered records since 1963, and these have been incorporated in the Account of Species, although not in overall numerical estimates, which are based on the quantitative lists mentioned above.

Recent Research on Birds

A brief summary is given here of research on birds carried out on Sable Island since 1967. Numerical and seasonal data resulting from these studies are included in the Account of Species.

I began a long-term study in May 1968 on the island's only endemic nesting bird, the Ipswich Sparrow, which next year was adopted by W. Stobo as the subject of doctoral research (Stobo 1973). As almost all nest on the island (a handful nests on the mainland, mated to Savannah Sparrows), and as it is relatively imperturbable, the bird offers advantages for study. A monograph on the subspecies (Stobo & McLaren 1975) gives many descriptions and analyses of its special life-history features. Between about 2000 and 3000 individuals returned each spring from 1967 to 1973, some pausing on the nearby mainland to await suitable weather. Males were vigorously territorial, and quite often bigamous, with the females out of phase in nesting cycles. A few females had as many as 4 successive successful broods in a season. Recruitment of fledged young (in late-summer censuses) was independent of breeding-population density, but much affected by weather. On the other hand, population density in late summer appeared to influence overwinter survival rate. Detailed measurements of live birds showed infinitesimal overlap between the island race and Savannah Sparrows from nearby mainland beaches.

Further doctoral research on the Ipswich Sparrow was done by H.A. Ross (1979), in an attempt to determine how the conditions of a young bird's rearing—habitat, season, age of parent—affect its early growth and subsequent survival. Ross (1980a) confirmed that young adult sparrows produced fewer offspring than did older ones, but also found (Ross 1980b) that older adults produced smaller young, in an evident sacrifice of quality for quantity. Most interestingly, there was no differential overwinter survival of young birds with respect to various measures of growth rate and size on the nest (except, weakly, tarsus length) or to habitat, month of birth, or age or longevity of parents (Ross 1979).

A.R. Lock (1973) studied the breeding biology of the Great Black-backed and Herring Gulls in 1969-1971. The island offered an unusual opportunity to study reproductive success in a setting remote from sources of food in garbage or fisheries wastes. His work supplied many details of the nesting cycles and behavior of the 2 species on the island. His major conclusion was that the Herring Gull population is unable to supply the food demands of its young in summer, so that it is not self-sustaining. The larger black-backs, because of their superior ability to range offshore and catch fish, and also because they exploit other seabirds, are self-sustaining as a population.

E.H. Miller (1977) did doctoral research on the Least Sandpiper on the island in 1975 and 1976. He showed that about 37% of eggs laid produced fledged young, so that the birds are quite successful on the island, near the southern limit of their nesting range. From extensive analysis of movements, displays and songs, Miller (1979) concluded that males make display flights over and defend exclusive mating territories. The males have a greater role in incubation and care of the brood than do females. In spite of the fact that the nesting season is more prolonged than in most northern sandpipers, the birds do not depart from a conservative, monogamous, single-clutch breeding system.

Jean Burton (1974) did his doctoral research on southbound shorebird migration in eastern North America, using Sable Island as a convenient locale in 1970 and 1971. Returns from the 1912 individuals banded there, together with studies of weights of the birds and their arrivals and departures in relation to weather, helped to illuminate major features of this migration. McNeil and Burton (1973; 1977) concluded that species with large fat reserves, such as White-rumped Sandpiper and Red Knot, together with the fattest individuals of Least Sandpiper, Short-billed Dowitcher and Semipalmated Sandpiper, make oversea, nonstop flights from the Maritimes to the Lesser Antilles, at least.

Bird Habitats and Bird Finding

The island is home for a number of breeding species, offers normal habitats on their usual migratory route for shorebirds and waterfowl, but is an unusual place in an unusual setting for the majority of species that have occurred there. Nevertheless, there are places on the island where many birds are attracted, and where particular kinds are found. Figure 1 should be consulted in connection with the following descriptions.

Truly pelagic species can be seen at times from anywhere along the island, especially when winds are easterly. However, much the best observing is from the island's tips, where pelagic birds can be seen rounding the ends of the island, and sometimes feeding in the turbulent, shallow waters. The outermost lengths of the island are also resting places for such pelagic birds as Kittiwakes, and occasional rare terns and gulls.

The extensive, unvegetated beaches on the island are used by nesting gulls and terns near the island's tips, and elsewhere by roosting flocks of gulls and terns, which can be scanned for occasional rarities. Although some shorebirds are to be found anywhere along the edge of the sea, the greatest concentrations occur seasonally on the often-flooded areas around the remnants of Wallace Lake. The westernmost and largest remnant has the largest concentrations, and the deeper part attracts occasional sea ducks or cormorants.

Waterbirds, herons, rallids, and shorebirds are to be looked for on and around the island's numerous brackish and fresh ponds. The complex of fresh ponds between West Light and the Meteorological Station is the best place for nesting ducks and shorebirds and for many visiting species. The areas just southwest of West Light have been recently protected from saltwater incursions by a large dyke, and the sandy-bottomed ponds often have unusual shorebirds. The generally brackish ponds at Old No. 3 Lifesaving Station are especially rich in shorebird species. Dykes and sandfencing are being established to prevent excessive inundation of some of these areas by seawater, which will help maintain the habitat for use by birds. Some smaller ponds on the island are worth searching for birds. Series of ponds about 0.5 km and 2 km east of the westernmost basin of Wallace Lake are not very deep or vegetationally rich, but do have unexpected species at times. The relatively deep pond 1.3 km west of No. 3 Station is good for waterfowl. The very small, shallow, but vegetationally diverse pond 0.3 km northwest of this Station has produced numbers of rare herons and rallids. Unfortunately, it seems to be filling in with sand during recent years.

Some landbird migrants are at home in the dunes, but most are strongly attracted to more densely vegetated areas. Areas around ponds are always the best places to find birds in spring. A systematic search of "high" shrubs (i.e.$>$0.3 m) is worthwhile. However, in late summer and autumn the island is greatly transformed by the growth of marram grass (*Ammophila breviligulata*), and especially by thick growths of beach pea (*Lathyrus japonicus*) and seaside goldenrod (*Solidago sempervirens*) on the tops of some dunes. These insect-rich, virtual thickets of herbaceous growth attract large numbers of passerines, including hordes of juvenile Ipswich Sparrows, between about late August and the beginning of winter. Perhaps because it is the first attractive landfall for birds displaced over the sea beyond the island, the lush top and southern slope of the long, easternmost dune are excellent places for birds. Birds are also often very concentrated on the flanks of the dunes 0.5 km southwest of West Light, perhaps gathering there from the length of the island before flying in a westerly direction to regain their normal flight paths.

Finally, it is a great convenience for observers that man-made structures—buildings, towers and fences—are much frequented by landbirds using them as substitute trees. Many of the most interesting birds seen on the island have occurred on and around the occupied house nearest West Light. The Meteorological Station tends to attract somewhat fewer birds. Birds can also be found around the rapidly collapsing buildings at Old Main Station, and especially in the nearby rose garden (*Rosa rugosa*) planted in 1901 but, alas, becoming inundated by sand in recent years. The nearby buildings established recently by the Nova Scotian government should also be explored. The old house near East Light, recently abandoned by researchers from the federal Department of Fisheries and Oceans, has not been strongly attractive to birds, and the newly built house to the southeast nearer the beach may be similarly unattractive, probably because of the lack of dense vegetation in the area. The long-abandoned house at Old No. 3 Station is now reduced to piles of rubble, within which lurks an occasional bird of interest. It should also be stressed here that dead birds are most frequent in and around buildings and under towers. Such corpses have supplied confirming evidence for the occurrence of unusual species and should be looked for.

Nesting Species

The species that nest or have nested on Sable Island include some obvious ones and a few surprises (Table II) that will be detailed in the Account of Species. In addition to these well-authenticated breeding birds, there are plausible but unsupported indications that Osprey, and possibly even Gull-billed Tern, nested in the last century. However, statements in the literature (see Account of Species) that "storm petrels", Razorbill, "yellowlegs", and Willet have nested are almost certainly in error.

A few species have shown breeding behavior on the island and could con-

Table II Birds that nest or have nested on Sable Island.

Species	Comments
Black Duck	Regular and common
Pintail	Few in recent years
Green-winged Teal	Few in recent years
Blue-winged Teal	Few in recent years
Red-breasted Merganser	Regular and common
Ring-necked Pheasant	Introduced 1961, extinct 1971
Semipalmated Plover	Regular, now uncommon
Piping Plover	Last known nesting in 1964
Common Snipe	In 1968 and perhaps earlier
Spotted Sandpiper	Regular, now uncommon
Least Sandpiper	Regular, quite common
Great Black-backed Gull	Since ca. 1920 (?), now common
Herring Gull	Since ca. 1920 (?), now common
Common Tern	Regular and abundant
Arctic Tern	Regular and abundant
Roseate Tern	Now diminishing rapidly
Tree Swallow	Single pairs, 1975, 1977
Barn Swallow	Pairs in ca. 1887, 1907, several 1976-1978
Common Crow	1948 (?), and 1-2 pairs since 1967
Common Starling	Regular and uncommon since ?
House Sparrow	Began 1930 (?), extinct 1970
Brown-headed Cowbird	Parasitized Ipswich Sparrows, 1963, 1968
Savannah Sparrow (mainland race)	A few miscegenates with Ipswich Sparrows
Ipswich Sparrow	Regular and abundant
Song Sparrow	1 pair, 2 broods, 1977

ceivably have nested, or might nest some time in the future. These have included Killdeer, Water Pipit and Red-winged Blackbird.

Regional Migrants

Coastal localities in general and islands in particular are often thought to give a very abnormal picture of regional migration. It is true that many vagrants and out-of-season birds occur in such settings, and these will be considered in later sections. However, the great majority of individuals on Sable Island are of species that are found simultaneously on the nearby mainland. Some of these may be birds for which the island is on route to their normal destinations—e.g. shorebirds (McNeil & Burton 1977) and some passerines (Williams et al. 1977)—flying across the ocean to South America. Landbirds that nest in Newfoundland may also pass near Sable Island routinely on their ways to and from the mainland farther south and west. The list of wood warblers on the island is instructive. Among species that nest in Nova Scotia, those that do not breed in Newfoundland (Godfrey 1966; some have been found nesting since, but the criterion is still valid in separating the 2 groups) are: Nashville, Parula, Cape May, Black-throated Blue, Blackburnian, Chestnut-sided, Bay-breasted, and Canada Warblers. These species averaged significantly less common on Sable Island than did those that nest in Newfoundland (numbers of individuals in Table III, spring and autumn combined; Mann-Whitney rank sums test, P = 0.02). The extreme exceptions to the rule that non-Newfoundland species are scarce are the Cape May and Bay-breasted Warblers, but these have certainly responded in recent years to spruce budworm outbreaks in Cape Breton, and perhaps Newfoundland. Two other passerines are of interest. Neither the Grey-cheeked Thrush nor the White-crowned Sparrow is reported at all commonly on mainland Nova Scotia during migration, especially in spring, yet they are very regular on Sable Island, perhaps only slightly deflected on overwater crossings to Newfoundland and Labrador.

The list of Nova Scotian nesting species (per Tufts 1973) that have not yet occurred on the island is also instructive. The 8 species are either very rare or localized in the province (Cooper's Hawk, Gray Partridge, Loggerhead Shrike), or are essentially nonmigratory, though sometimes eruptive, forest species (Spruce Grouse, Ruffed Grouse, Great Horned Owl, Pileated Woodpecker, Boreal Chickadee). Even such supposedly sedentary species as House Sparrow have occurred as migrants on the island. Transients in the province (i.e. not vagrants as defined in the later section on Vagrants) that have not been sighted on the island are: Horned Grebe, King Eider, Golden Eagle, Gyrfalcon, Great Gray Owl, and Northern Three-toed Woodpecker. Only the first of these is at all regular in the province.

Even if the relative abundances of various migratory species are strongly distorted compared with those on mainland Nova Scotia, the various dates of arrival and departure of migrants should reflect regional patterns more faithfully. The dates used to construct Table III are considered to be normal ones for the island and the region. Some extremely early and extremely late dates are mentioned under individual species in the Account of Species. The migration table for the island has one feature that cannot be matched in records of most species on the mainland. On the island it is possible to obtain data on the cessation of migration in spring and its resumption in autumn, obscured by the presence of summer residents on the mainland. This allows estimates to be made of the relative lengths of migration seasons of different species, either from median dates of first and last sightings or from extreme dates of such sightings (Table III).

Some of the earliest and latest dates in Table III, although considered normal, are records for the province (Tufts 1973, and subsequent issues of the *Nova Scotia Bird Society Newsletter*). However, the median dates are of interest in suggesting that migration *routinely* carries on much later in spring than might be supposed for many species, and begins again quite early in summer for some species. Even such early spring migrants as American Robins and Song Sparrows are still on the move in late May, and often into June. Similarly the abundantly represented forest passerines are generally on the move well before the end of August. Observations are perhaps least adequate for the late-autumn period. Examples will be given in the Account of Species of some birds that have appeared routinely later in the season than might be suggested by the median dates of last sightings in Table III.

The observations by the Bouteilliers on arrival dates of regional migrants afford many comparisons with more recent observations. Dates for species that were sufficiently regular to be listed by them for 3 springs or 3 autumns during 1901-1908 are summarized in Table IV. Other records made by them of less common species or of early, late, or unseasonable sightings, will be referred to in the Account of Species.

Table III Migration table, 1967-1979, for selected species that have occurred during at least 5 springs or falls (see text).

	SPRING MIGRATION							FALL MIGRATION						
	Number of			First Seen		Last Seen		Number of			First Seen		Last Seen	
SPECIES	years years	occur-rences	individ-uals	earliest	median	median	latest	years years	occur-rences	individ-uals	earliest	median	median	latest
Great Blue Heron	9	18	23	16 Mar.	1 May	24 May	5 June	8	15	21	17 Aug.	26 Oct.	7 Nov.	4 Dec.
Snowy Egret	5	7	8	24 Mar.	10 May	23 May	10 June	2	3	5	22 Sept.	1 Oct.	14 Oct.	6 Nov.
Little Blue Heron	2	2	2	18 Apr.	-	-	1 May	5	6	8	17 Aug.	12 Sept.	29 Oct.	15 Nov.
Green Heron	8	9	9	30 Apr.	1 June	8 June	11 June	3	3	5	23 Sept.	14 Oct.	16 Nov.	16 Nov.
Yellow-crowned Night Heron	0	-	-	-	-	-	-	10	18	20	11 July	24 Aug.	14 Sept.	15 Nov.
American Bittern	4	4	4	22 May	28 May	28 May	29 June	8	17	18	12 Aug.	17 Oct.	6 Nov.	4 Dec.
Glossy Ibis	5	6	8	3 May	9 May	20 May	28 May	1	1	1	8 Aug.	-	-	8 Aug.
Canada Goose	11	18	104	1 Mar.	13 Apr.	16 May	12 June	10	18	181	27 Aug.	19 Oct.	22 Nov.	30 Dec.
Mallard	5	8	15	19 Mar.	2 June	3 June	22 June	4	4	5	12 Sept.	9 Nov.	9 Nov.	23 Nov.
Northern Pintail	10	13	39	28 Apr.	10 May	5 June	1 July	10	14	59	16 Aug.	13 Sept.	17 Oct.	20 Nov.
Greenwinged Teal	10	18	41	31 Mar.	12 May	10 June	2 July	12	32	546	17 July	10 Sept.	22 Oct.	30 Nov.
Bluewinged Teal	11	27	59	30 Mar.	30 Apr.	9 June	22 June	12	23	307	11 Aug.	1 Sept.	22 Sept.	24 Nov.
Wood Duck	5	6	12	29 Mar.	28 May	28 May	14 June	2	2	3	17 Nov.	-	-	29 Nov.
Ring-necked Duck	5	6	6	15 Apr.	18 May	8 June	18 June	3	3	7	25 Sept.	16 Oct.	17 Oct.	24 Oct.
Northern Goshawk	0	-	-	-	-	-	-	6	12	14	15 Sept.	25 Sept.	10 Oct.	11 Dec.
Rough-legged Hawk	1	1	1	11 Apr.	-	-	11 Apr.	7	11	26	28 Aug.	1 Oct.	1 Nov.	19 Nov.
Marsh Hawk	3	4	4	28 Mar.	1 May	17 May	26 May	9	11	11	13 Aug.	15 Sept.	19 Sept.	14 Nov.
Osprey	10	11	11	24 May	31 May	3 June	19 June	4	4	4	17 July	7 Oct.	7 Oct.	23 Nov.
American Kestrel	12	34	38	20 Mar.	4 Apr.	28 May	15 June	13	35	56	16 Aug.	15 Sept.	3 Nov.	29 Dec.
Merlin	8	15	15	26 Mar.	20 May	1 June	11 June	10	20	22	30 July	16 Sept.	16 Oct.	11 Dec.
Sora	1	1	1	23 May	-	-	24 May	7	12	21	21 July	27 Aug.	10 Sept.	19 Sept.
American Coot	2	2	2	21 May	30 May	1 June	8 June	8	15	60	23 July	12 Oct.	16 Nov.	30 Nov.
Semipalmated Plover	13	-	55	3 May	16 May	-	-	13	-	1621	-	-	11 Oct.	30 Nov.
Piping Plover	3	6	11	23 Apr.	4 May	10 June	11 June	6	7	19	22 Aug.	20 Sept.	20 Sept.	24 Nov.
Killdeer	8	12	18	1 Apr.	13 May	4 June	27 June	12	39	79	4 July	23 Aug.	15 Nov.	28 Dec.
American Golden Plover	1	1	1	16 June	-	-	16 June	12	28	1415	6 Aug.	25 Aug.	7 Oct.	6 Nov.
Black-bellied Plover	11	27	85	22 Apr.	25 May	5 June	20 June	13	42	5155	15 July	2 Aug.	17 Oct.	1 Dec.
American Woodcock	6	11	11	3 Apr.	2 May	18 May	29 May	7	10	13	12 Sept.	20 Sept.	12 Oct.	10 Nov.

Common Snipe	12	21	32	29 Mar.	17 May	2 June	19 June	12	39	121	24 July	15 Aug.	24 Oct.	30 Nov.
Whimbrel	4	4	4	5 May	11 May	11 May	24 May	13	33	286	2 July	12 Aug.	18 Sept.	26 Nov.
Upland Sandpiper	7	12	13	26 Apr.	13 May	3 June	27 June	6	7	9	14 July	9 Sept.	12 Sept.	19 Nov.
Greater Yellowlegs	13	68	153	17 Apr.	1 May	19 June	29 June	13	78	1257	1 July	16 July	13 Nov.	20 Nov.
Lesser Yellowlegs	9	11	19	2 May	20 May	26 May	7 June	12	49	424	9 July	11 Aug.	21 Sept.	28 Nov.
Solitary Sandpiper	5	5	5	28 Apr.	25 May	26 May	8 June	11	24	53	21 July	25 Aug.	15 Sept.	16 Nov.
Willet	13	30	61	30 Apr.	16 May	10 June	30 June	6	18	31	15 July	27 July	17 Oct.	29 Nov.
Spotted Sandpiper	13	-	40	27 Apr.	29 May	-	-	13	-	60	-	-	15 Sept.	25 Oct.
Ruddy Turnstone	7	9	10	14 May	26 May	3 June	22 June	12	46	604	5 July	9 Aug.	16 Sept.	1 Dec.
Red Knot	5	6	13	9 May	24 May	1 June	8 June	8	16	92	14 July	24 Aug.	15 Sept.	10 Nov.
Least Sandpiper	13	-	150	25 Apr.	11 May	-	-	13	-	575	-	-	14 Sept.	17 Nov.
Baird's Sandpiper	0	-	-	-	-	-	-	5	8	18	21 Aug.	13 Sept.	16 Sept.	22 Sept.
White-rumped Sandpiper	3	3	24	20 May	8 June	8 June	10 June	12	31	1927	25 July	17 Aug.	27 Sept.	12 Dec.
Pectoral Sandpiper	2	2	10	13 May	-	-	26 June	12	37	227	14 July	31 July	4 Oct.	5 Nov.
Dunlin	1	1	1	29 Apr.	-	-	29 Apr.	5	7	41	23 Aug.	15 Sept.	19 Sept.	30 Nov.
Semipalmated Sandpiper	9	15	74	3 May	26 May	11 June	5 July	13	31	3169	10 July	22 July	13 Sept.	22 Nov.
Sanderling	9	19	403	23 Apr.	16 May	30 May	8 June	12	48	4510	13 July	25 July	-	-
Stilt Sandpiper	3	3	3	8 May	8 June	8 June	13 June	10	13	29	10 July	26 Aug.	10 Sept.	15 Oct.
Buff-breasted Sandpiper	1	1	1	20 May	-	-	20 May	6	10	27	23 Aug.	30 Aug.	14 Sept.	16 Sept.
Hudsonian Godwit	0	-	-	-	-	-	-	7	10	44	2 July	23 Aug.	11 Sept.	30 Sept.
Long-billed Dowitcher	0	-	-	-	-	-	-	5	6	14	26 Aug.	13 Sept.	13 Sept.	2 Oct.
Short-billed Dowitcher	6	8	39	3 May	15 May	18 May	13 June	12	47	1109	29 June	15 July	16 Sept.	24 Oct.
Wilson's Phalarope	2	2	2	23 May	-	-	13 June	6	11	21	22 Aug.	1 Sept.	17 Sept.	15 Nov.
Black Tern	6	7	7	18 May	10 June	10 June	13 June	10	20	39	3 July	11 Aug.	4 Sept.	24 Sept.
Mourning Dove	3	6	6	29 Mar.	21 May	8 June	17 June	13	37	180	8 July	1 Sept.	9 Nov:	19 Dec.
Black-billed Cuckoo	5	5	5	12 May	10 June	10 June	3 July	10	21	29	8 July	13 Aug.	1 Oct.	26 Nov.
Yellow-billed Cuckoo	3	4	4	11 May	30 May	17 June	17 June	6	12	12	10 Aug.	5 Sept.	16 Oct.	13 Nov.
Common Nighthawk	9	15	16	24 May	3 June	12 June	23 June	6	12	15	3 July	18 July	3 Sept.	10 Oct.
Chimney Swift	13	27	63	7 May	19 May	3 June	11 June	6	9	35	24 July	28 Aug.	5 Sept.	9 Sept.
Ruby-throated Hummingbird	3	4	6	23 May	24 May	31 May	3 June	5	8	9	16 July	25 Aug.	13 Sept.	3 Oct.
Belted Kingfisher	11	25	30	11 Apr.	1 May	28 May	20 June	10	27	32	26 July	6 Sept.	14 Oct.	10 Dec.
Common Flicker	10	19	23	2 Apr.	20 Apr.	15 May	30 May	12	28	102	20 July	8 Sept.	23 Oct.	24 Nov.

SPECIES	SPRING MIGRATION							FALL MIGRATION						
	Number of			First Seen		Last Seen		Number of			First Seen		Last Seen	
	years years	occur-rences	individ-uals	earliest	median	median	latest	years years	occur-rences	individ-uals	earliest	median	median	latest
Downy Woodpecker	6	11	11	12 Apr.	12 May	24 May	13 June	9	16	16	16 Aug.	19 Sept.	2 Oct.	13 Nov.
Eastern Kingbird	13	46	133	30 Apr.	16 May	27 June	7 July	8	23	73	2 Aug.	1 Sept.	17 Sept.	26 Nov.
Great Crested Flycatcher	5	5	5	5 June	11 June	11 June	29 June	6	10	20	4 Sept.	7 Sept.	14 Sept.	17 Oct.
Eastern Phoebe	9	13	16	12 Apr.	16 May	29 May	16 June	4	6	8	22 July	1 Sept.	11 Sept.	17 Oct.
Yellow-bellied Flycatcher	13	38	200	29 May	2 June	20 June	4 July	10	22	51	17 July	27 Aug.	10 Sept.	20 Sept.
Empidonax spp.	13	29	94	1 May	25 May	15 June	30 June	11	22	49	1 Aug.	26 Aug.	14 Sept.	4 Oct.
Eastern Wood Pewee	13	38	148	16 May	27 May	12 June	27 June	9	12	17	24 July	11 Sept.	13 Sept.	27 Sept.
Olive-sided Flycatcher	11	15	20	19 May	8 June	11 June	19 June	3	3	3	27 Aug.	4 Sept.	4 Sept.	8 Sept.
Horned Lark	6	8	13	4 Apr.	11 May	22 May	5 June	6	10	102	27 Sept.	9 Oct.	16 Oct.	15 Nov.
Tree Swallow	13	28	402	18 Apr.	8 May	19 June	30 June	10	41	419	20 July	2 Aug.	28 Sept.	16 Nov.
Bank Swallow	13	41	118	9 May	19 May	15 June	1 July	8	16	230	15 July	16 Aug.	3 Sept.	13 Nov.
Barn Swallow	13	51	546	17 Apr.	8 May	13 June	8 July	10	32	307	13 July	12 Aug.	12 Sept.	15 Nov.
Cliff Swallow	13	24	65	3 May	24 May	5 June	1 July	7	11	44	12 July	25 Aug.	5 Sept.	13 Nov.
Purple Martin	11	30	69	12 Apr.	2 May	12 June	2 July	7	8	15	26 Aug.	22 Sept.	22 Sept.	28 Oct.
Red-breasted Nuthatch	8	12	20	7 May	16 May	4 June	26 June	12	23	48	23 July	17 Aug.	8 Sept.	18 Nov.
Winter Wren	5	10	10	3 Apr.	21 Apr.	9 May	2 June	3	4	6	2 Oct.	17 Oct.	23 Oct.	1 Nov.
Northern Mockingbird	3	3	4	31 May	31 May	3 June	14 June	11	25	39	17 July	10 Sept.	5 Nov.	16 Nov.
Gray Catbird	13	42	102	27 Apr.	11 May	12 June	1 July	10	21	49	20 July	19 Sept.	18 Oct.	26 Nov.
Brown Thrasher	9	19	22	28 Apr.	16 May	12 June	29 June	6	7	7	18 Sept.	24 Sept.	26 Sept.	20 Oct.
American Robin	12	34	162	29 Mar.	3 Apr.	24 May	12 June	12	42	681	31 July	10 Sept.	7 Nov.	29 Dec.
Wood Thrush	6	8	11	10 May	19 May	28 May	6 June	2	3	3	10 Sept.	1 Oct.	6 Oct.	19 Oct.
Hermit Thrush	13	35	60	28 Mar.	3 May	1 June	13 June	7	14	16	18 Sept.	9 Oct.	21 Oct.	18 Dec.
Swainson's Thrush	13	37	128	14 May	25 May	10 June	26 June	8	15	24	23 Aug.	19 Sept.	13 Oct.	20 Nov.
Gray-cheeked Thrush	13	34	60	9 May	24 May	11 June	21 June	8	16	33	2 Sept.	13 Sept.	25 Oct.	13 Nov.
Veery	13	22	32	10 May	25 May	4 June	20 June	2	2	2	12 Sept.	17 Sept.	17 Sept.	21 Sept.
Golden-crowned Kinglet	6	8	24	20 Apr.	3 May	14 May	18 May	0	-	-	-	-	-	-
Ruby-crowned Kinglet	13	27	155	7 Apr.	27 Apr.	31 May	15 June	10	17	59	26 Aug.	19 Sept.	17 Oct.	20 Nov.
Water Pipit	12	28	80	30 Apr.	19 May	13 June	21 June	10	16	146	9 Sept.	13 Sept.	17 Oct.	14 Nov.

Cedar Waxwing	12	18	58	22 May	3 June	8 June	26 June	12	40	466	17 July	16 Aug.	4 Oct.	8 Nov.
Solitary Vireo	5	5	5	17 May	20 May	20 May	5 June	1	1	1	29 Aug.	-	-	29 Aug.
Red-eyed Vireo	11	15	29	28 May	6 June	8 June	22 June	6	10	21	19 Aug.	3 Sept.	11 Sept.	20 Sept.
Philadelphia Vireo	2	3	3	27 May	4 June	4 June	12 June	5	5	5	23 Aug.	15 Sept.	15 Sept.	16 Oct.
Black-and-White Warbler	13	30	71	1 May	19 May	8 June	18 June	13	38	126	5 Aug.	20 Aug.	1 Oct.	5 Nov.
Prothonotary Warbler	2	2	2	20 May	-	-	9 June	5	6	9	10 Aug.	10 Sept.	15 Sept.	1 Oct.
Tennessee Warbler	13	33	54	16 May	26 May	11 June	29 June	7	12	63	12 Aug.	31 Aug.	13 Sept.	23 Sept.
Nashville Warbler	8	13	16	16 May	25 May	1 June	15 June	5	5	8	5 Sept.	12 Sept.	13 Sept.	29 Sept.
Northern Parula Warbler	13	23	63	13 May	23 May	9 June	24 June	2	2	2	12 Sept.	-	-	12 Oct.
Yellow Warbler	13	43	103	13 May	20 May	14 June	26 June	13	39	188	22 July	6 Aug.	16 Sept.	20 Oct.
Magnolia Warbler	13	41	116	7 May	17 May	16 June	25 June	12	24	49	28 July	23 Aug.	16 Sept.	20 Oct.
Cape May Warbler	11	27	39	12 May	23 May	5 June	2 July	12	26	253	11 Aug.	7 Sept.	19 Sept.	20 Nov.
Black-throated Blue Warbler	7	9	9	18 May	30 May	30 May	10 June	6	7	9	1 Sept.	16 Sept.	26 Sept.	17 Oct.
Yellow-rumped Warbler	13	66	476	10 Apr.	2 May	10 June	22 June	13	47	1529	31 July	22 Aug.	15 Nov.	20 Dec.
Black-throated Green Warbler	13	26	52	4 May	27 May	9 June	20 June	12	15	27	19 Aug.	9 Sept.	13 Sept.	17 Oct.
Blackburnian Warbler	12	21	30	10 May	23 May	6 June	19 June	10	11	12	21 Aug.	14 Sept.	14 Sept.	14 Oct.
Chestnut-sided Warbler	7	12	16	10 May	28 May	3 June	15 June	5	7	8	20 Aug.	6 Sept.	14 Sept.	15 Oct.
Bay-breasted Warbler	12	35	90	7 May	22 May	8 June	26 June	13	31	141	15 Aug.	26 Aug.	19 Sept.	13 Nov.
Blackpoll Warbler	13	46	427	14 May	20 May	17 June	26 June	13	28	352	21 July	10 Sept.	2 Oct.	28 Nov.
Prairie Warbler	0	-	-	-	-	-	-	11	33	46	8 Aug.	26 Aug.	16 Sept.	16 Oct.
Palm Warbler	12	31	61	18 April	2 May	24 May	7 June	10	29	95	10 Aug.	13 Sept.	10 Nov.	22 Dec.
Ovenbird	13	24	36	14 May	26 May	9 June	14 June	9	20	32	13 Aug.	31 Aug.	19 Sept.	14 Nov.
Northern Waterthrush	13	40	113	16 May	23 May	12 June	27 June	12	30	84	3 Aug.	10 Aug.	14 Sept.	17 Oct.
Mourning Warbler	12	23	34	30 May	8 June	15 June	30 June	3	6	13	27 Aug.	31 Aug.	15 Sept.	16 Oct.
Common Yellowthroat	13	40	91	1 May	19 May	15 June	21 June	9	15	29	5 Aug.	12 Sept.	25 Sept.	24 Oct.
Yellow-breasted Chat	0	-	-	-	-	-	-	8	14	28	27 Aug.	10 Sept.	14 Sept.	22 Oct.
Hooded Warbler	3	5	5	15 May	20 May	10 June	14 June	7	9	11	7 Aug.	10 Sept.	15 Sept.	17 Oct.
Wilson's Warbler	13	27	79	16 May	25 May	12 June	29 June	11	24	58	30 July	25 Aug.	12 Sept.	25 Sept.
Canada Warbler	12	25	69	22 May	31 May	12 June	21 June	7	8	13	25 Aug.	31 Aug.	13 Sept.	17 Oct.
American Redstart	13	42	103	17 May	25 May	20 June	27 June	13	55	327	12 Aug.	25 Aug.	18 Oct.	14 Nov.
Bobolink	13	31	76	16 May	23 May	8 June	19 June	9	16	271	21 Aug.	6 Sept.	16 Sept.	18 Oct.
Yellow-headed Blackbird	1	1	1	8 May	-	-	17 May	6	10	12	15 Aug.	3 Sept.	21 Sept.	12 Oct.
Red-winged Blackbird	13	27	41	2 Apr.	10 May	25 May	24 May	8	21	274	20 Aug.	9 Sept.	30 Oct.	12 Dec.

SPECIES	SPRING MIGRATION							FALL MIGRATION						
	Number of			First Seen		Last Seen		Number of			First Seen		Last Seen	
	years	occurrences	individuals	earliest	median	median	latest	years	occurrences	individuals	earliest	median	median	latest
Orchard Oriole	6	6	6	16 May	24 May	24 May	22 June	4	4	5	10 Sept.	24 Sept.	24 Sept.	3 Oct.
Northern Oriole	9	15	19	7 May	18 May	31 May	11 June	13	44	290	19 Aug.	4 Sept.	2 Oct.	18 Dec.
Rusty Blackbird	12	29	284	29 Mar.	3 May	24 May	7 June	10	23	535	5 Sept.	18 Sept.	23 Oct.	21 Dec.
Common Grackle	10	21	92	2 Apr.	1 May	4 June	11 June	5	8	21	12 Sept.	28 Sept.	20 Nov.	12 Dec.
Brown-headed Cowbird	12	24	251	4 Apr.	23 Apr.	25 May	31 June	13	41	332	19 July	15 Aug.	24 Oct.	12 Dec.
Scarlet Tanager	5	6	6	10 May	24 May	24 May	7 June	6	6	15	11 Sept.	15 Sept.	25 Sept.	27 Oct.
Rose-breasted Grosbeak	13	25	45	25 Apr.	17 May	3 June	24 June	11	13	42	15 Aug.	13 Sept.	16 Sept.	29 Oct.
Indigo Bunting	10	16	20	25 Apr.	23 May	9 June	18 June	4	5	5	14 Aug.	14 Oct.	25 Oct.	13 Nov.
Dickcissel	3	4	4	27 Apr.	3 May	19 May	24 May	6	18	47	27 Aug.	20 Sept.	25 Oct.	30 Dec.
Evening Grosbeak	10	29	70	2 Apr.	10 May	31 May	22 June	12	27	344	4 Aug.	4 Oct.	12 Nov.	28 Dec.
Purple Finch	13	26	113	18 Apr.	13 May	10 June	6 July	11	27	212	24 July	14 Aug.	29 Oct.	11 Dec.
Pine Grosbeak	5	7	7	9 May	24 May	6 June	14 June	7	9	25	5 Aug.	18 Oct.	26 Oct.	17 Nov.
Common Redpoll	5	5	37	8 Apr.	22 Apr.	24 Apr.	10 June	1	1	6	4 Nov.	-	-	6 Nov.
Pine Siskin	11	27	77	18 Apr.	26 May	14 June	2 July	8	17	250	15 July	10 Aug.	1 Oct.	5 Nov.
American Goldfinch	9	19	32	14 May	30 May	11 June	26 June	5	9	12	3 Aug.	28 Aug.	1 Oct.	17 Oct.
White-winged Crossbill	1	1	2	23 June	-	-	28 June	5	14	21	25 July	7 Aug.	7 Nov.	24 Dec.
Rufous-sided Towhee	4	5	8	15 May	18 May	1 June	15 June	5	5	24	23 Aug.	6 Oct.	12 Oct.	19 Oct.
Savannah Sparrow	11	19	47	29 Apr.	16 May	1 June	14 June	8	12	39	1 Sept.	7 Oct.	19 Oct.	13 Nov.
Dark-eyed Junco	12	34	233	20 Mar.	3 Apr.	1 June	10 June	11	28	321	9 Sept.	26 Sept.	20 Nov.	28 Dec.
Tree Sparrow	5	7	9	22 Apr.	13 May	19 May	26 May	3	4	13	1 Oct.	7 Oct.	27 Oct.	4 Nov.
Chipping Sparrow	7	12	17	30 Apr.	19 May	2 June	11 June	8	10	20	4 Aug.	15 Sept.	16 Sept.	17 Oct.
White-crowned Sparrow	13	27	129	23 Apr.	8 May	2 June	12 June	10	19	84	16 Sept.	25 Sept.	1 Nov.	8 Dec.
White-throated Sparrow	13	55	452	2 Apr.	26 Apr.	9 June	16 June	13	42	330	29 Aug.	15 Sept.	28 Oct.	26 Dec.
Fox Sparrow	12	29	187	22 Mar.	3 Apr.	3 May	14 June	11	21	144	15 Sept.	3 Oct.	25 Oct.	16 Dec.
Lincoln's Sparrow	13	22	77	17 May	25 May	5 June	13 June	7	12	19	28 Aug.	19 Sept.	18 Oct.	17 Nov.
Swamp Sparrow	13	32	77	14 May	17 May	3 June	16 June	8	13	45	1 Sept.	23 Sept.	3 Oct.	10 Nov.
Song Sparrow	12	35	175	24 Mar.	7 Apr.	28 May	11 June	8	9	31	12 Sept.	12 Oct.	12 Oct.	26 Nov.
Lapland Longspur	3	4	4	30 Apr.	14 May	14 May	21 May	6	7	183	14 Sept.	29 Oct.	31 Oct.	19 Nov.
Snow Bunting	12	22	612	14 Mar.	6 Apr.	3 May	21 May	9	25	2345	2 Oct.	25 Oct.	-	-

Table IV Migration table, 1901-1908, for species recorded as first seen during at least 3 falls or 3 springs on the Bouteilliers' published and unpublished lists.

	Spring Migration			Autumn Migration		
Species	no.years	earliest	median	no.years	earliest	median
Pied-billed Grebe				3	28 Sept.	4 Oct.
Great Blue Heron	1	18 May	—	5	5 Aug.	5 Oct.
American Bittern	1	4 May	—	5	8 Sept.	4 Oct.
Blue-winged Teal				4	19 Sept.	18 Oct.
American Wigeon				3	28 Oct.	7 Nov.
Greater Scaup				7	18 Oct.	20 Nov.
Common Goldeneye				3	20 Oct.	28 Oct.
Bufflehead				4	11 Sept.	31 Oct.
Oldsquaw				6	20 Oct.	29 Oct.
White-winged Scoter				4	21 Oct.	26 Nov.
Osprey				3	26 Sept.	30 Sept.
Semipalmated Plover	6	23 Apr.	24 Apr.			
Piping Plover	5	25 Apr.	7 May			
Killdeer				3	22 Oct.	17 Nov.
Golden Plover				3	20 Aug.	20 Aug.
Black-bellied Plover	5	8 May	22 May	5	4 Aug.	16 Aug.
Common Snipe				5	5 July	13 July
Whimbrel*	1	10 June	—	3	18 July	20 July
Spotted Sandpiper	5	12 May	18 May			
Greater Yellowlegs	5	22 Apr.	5 May	7	5 July	10 July
Lesser Yellowlegs				4	5 July	3 Aug.
Ruddy Turnstone	2	25 May	6 June	3	12 July	3 Aug.
Pectoral Sandpiper				5	22 July	5 Aug.
White-rumped Sandpiper				8	14 July	1 Aug.
Least Sandpiper	7	30 Apr.	8 May			
Semipalmated Sandpiper				5	26 July	3 Aug.
Red Phalarope	7	4 May	21 May			
Common, Arctic Terns	7	23 Apr.	26 Apr.			
Roseate Tern	7	13 May	16 May			
Belted Kingfisher	3	14 Apr.	12 May	2	26 Sept.	2 Oct.
Common Flicker	1	27 Apr.	—	5	10 Sept.	16 Sept.
Eastern Kingbird	2	19 May	26 May	3	3 Aug.	7 Sept.
Yellow-bellied Flycatcher	4	25 May	14 June			
Horned Lark	3	23 Mar.	29 Mar.	3	20 Sept.	30 Sept.
Common Crow	5	20 Mar.	24 Mar.			
White-breasted Nuthatch				3	11 Sept.	20 Sept.
Red-breasted Nuthatch†	1	27 June	—	5	2 Aug.	7 Sept.
Brown Creeper	1	15 May	—	3	20 Sept.	25 Oct.
Northern Mockingbird				3	5 Sept.	20 Sept.
American Robin	6	20 Mar.	24 Mar.	7	9 Oct.	24 Oct.
Hermit Thrush	3	25 Apr.	24 May	6	20 Sept.	23 Oct.
Golden-crowned Kinglet°				5	29 Sept.	18 Oct.
Water Pipit	2	12 May	14 May	7	16 Sept.	19 Sept.

* Includes "curlew", unidentified to species.

† Includes "nuthatch", probably this species.

° Once as "Golden-crested Wren".

Species	Spring Migration no.years	 earliest	 median	Autumn Migration no.years	 earliest	 median
Cedar Waxwing	1	7 June	—	3	11 Sept.	12 Sept.
Northern Shrike				4	4 Nov.	23 Nov.
Black-and-white Warbler				6	20 Aug.	18 Sept.
Yellow Warbler	3	23 May	4 June	3	3 Aug.	3 Aug.
Magnolia Warbler	4	24 May	28 May	1	8 Oct.	—
Black-throated Blue Warbler				3	16 Sept.	28 Sept.
Yellow-rumped Warbler	2	10 May	22 May	5	15 Sept.	29 Sept.
Black-throated Green Warbler	3	10 May	25 May	3	12 Sept.	20 Sept.
Blackpoll Warbler	5	18 May	23 May			
Palm Warbler				3	16 Sept.	20 Sept.
House Sparrow	2	22 Apr.	6 May	5	4 Oct.	14 Oct.
Pine Siskin	5	23 May	3 June	1	4 Oct.	—
Vesper Sparrow	2	27 Apr.	8 May	3	20 Sept.	21 Oct.
Dark-eyed Junco	6	20 Mar.	11 Apr.	5	2 Oct.	5 Oct.
White-crowned Sparrow	3	13 May	25 May			
White-throated Sparrow	6	29 Mar.	28 Apr.	6	23 Sept.	26 Sept.
Fox Sparrow	4	20 Mar.	4 Apr.	5	29 Sept.	4 Oct.
Snow Bunting	2	21 Apr.	6 May	5	4 Oct.	7 Oct.

Absolute and Relative Abundances of Species

When censusing populations of Ipswich Sparrows on selected areas of vegetation (Stobo & McLaren 1975), and on occasion when searching known areas for banded sparrows, counts were kept of all other landbirds present on the areas covered. These allow estimates to be made of the numbers of such landbirds on the island (Table V). Unfortunately, there are few or no counts from some parts of the migration seasons, but there is weak indication of seasonal cycles in the low counts from early and late in spring and from late in autumn.

The variances of counts in midseason are very high (cf. counts in late May and in mid-September, Table V). The abundance of migrant landbirds on the island is strongly dependent on weather. After days of southwesterly or easterly winds, there may be very few. Following the passage of a cold front, with westerly or northwesterly winds, the dunes may seem relatively swarming with landbirds. These conditions may also bring large numbers of shorebirds (Burton 1974).

The estimated mean abundances of migrant landbirds on the island are very low: 359 (or about 1 individual/3 ha) in spring and 2366 (or about 2/ha) in autumn. These abundances are much lower than found in breeding bird surveys on the mainland, and elsewhere I have shown (McLaren 1981) that daily counts of birds on Sable Island are only about one-sixth to one-quarter as high as those made on the same days on Seal Island, Yarmouth Co., and Brier Island, Digby Co., nearer to the mainland of Nova Scotia. Clearly, Sable Island is off the normal routes of most landbirds, and may be actively avoided by many regional individuals (see McLaren 1981).

The extensive daily observations of birds on the island can be used to estimate relative abundances of species. Some birds were identifiable as individuals on successive days, but this could not be done with more frequent species, for which

Table V Estimated numbers of nonresident landbirds on the vegetated terrain (total ca. 1018 ha) of Sable Island, from censuses of selected areas.

Dates	% of terrain censused	Estimated no. (nearest 10)
Spring		
10-16 June 1971	52.0	130
27-29 June 1971	42.0	30
10-11 Apr. 1972	12.6	150
26 May—1 June 1975	3.8	820
17-22 June 1975	3.2	340
17-22 May 1977	19.7	860
23-24 May 1977	10.2	650
28-29 May 1977	6.0	470
24-29 May 1978	6.9	100
13-17 June 1979	6.9	40
Autumn		
12-13 Sept. 1972	6.9	4340
13-14 Sept. 1973	6.9	2940
24 Oct. 1973	2.1	1760
11-12 Sept. 1974	6.9	730
16 Oct. 1975	1.6	4590
13-16 Sept. 1977	6.9	1810
15 Nov. 1977	1.9	430
5-10 Sept. 1978	6.9	2330

an estimate of the residence time of individuals was needed. For this purpose, I used daily counts made by at least 2 active observers over at least 2 weeks (ignoring birds seen on the first and last days) in the vicinity of the Meterological Station and West Light, where birds were often quite sedentary. I chose species that were large or conspicuous because of habits or appearance: hawks, large flycatchers, swallows, jays, nuthatches (almost always on buildings), mimids, thrushes, icterids, tanagers, grosbeaks, buntings, and towhees. To minimize confusion, I chose only those species of the above that were relatively infrequent (<30 individuals in the period 1967-1979 on uncorrected lists). Many of these birds were in fact reported as individuals on successive days by observers. Altogether, 114 individuals of 25 species satisfied all criteria, and these were seen for an average of 3.7 days.

I assumed, therefore, that a species (or sex or age category) represented a new occurrence of individuals if not seen during the previous 4 days. Also, when a species was recorded in larger numbers than had occurred during the previous 4 days, the increment was assumed to be of new individuals. I made no attempt to correct for "turnover" of species that were present in about the same numbers for periods of more than 4 days; for these a single peak count often stood as a total for a period. Against this tendency to possible underestimation, there were periods of inactivity or bad weather that could lead to recounting of birds that were present, but not seen, for 4 or more days.

The 4-day rule may be inappropriate for shorebirds, which are known to make longer stopovers to gain resources for their extensive flights. Indeed, Burton (1974) found that some banded individuals stayed on the island for nearly 3 weeks. However, generally the areas of concentration of shorebirds around Wallace Lake (Fig 1) were surveyed infrequently, so that large counts were made at intervals considerably greater than 4 days.

Some judgement had to be made in using the sequences of numbers in the daily lists. Thus, birds counted during brief visits to other parts of the island were added to those counted during the same 4-day period in areas routinely surveyed. However, these were not assumed to have arrived as a new occurrence of the species on the day of the visit to the new area. Judgment was also used in dealing with some of the lists submitted by A. Richard, in which he estimated numbers seen during portions of some seasons (see Recent Records of Birds). His estimates in this form, made during times when other individuals were not making daily counts, were added to the overall estimates of relative abundances based on the 4-day rule. However, they could only be counted as a single occurrence of the species during that portion of the season.

The estimates of relative abundance of the more commonplace migrants and vagrants on the island (those that occurred during at least 5 springs or 5 autumns in the 13 years), are summarized in Table III. Seabirds, which do not depend on the terrain of the island and cannot be compared in abundance with those that use the island and its ponds, are excluded. I also exclude the abundant resident species: gulls, terns, Black Duck and Red-breasted Merganser, and Ipswich Sparrow. For the rest, the years in which it was seen give an impression of the regularity of the species. Relative abundance is self-evident, and an impression of the size and frequency of visits during a season can be gained from the figures on number of occurrences. (Numbers of occurrences are not included in Table III for the partly transient Semipalmated Plover and Least Sandpiper. For these the spring estimates of abundance are based on maximal seasonal counts of residents and autumn estimates on maximal July counts, assumed to be resident adults and offspring, to which were added later occurrences in the usual manner.)

Vagrants

Sable Island is certainly one of the best localities in eastern North America for the occurrence of vagrant species (Table VI). Among species that nest in North America, a vagrant is defined as a species that did not nest in Nova Scotia prior to 1971 (Tufts 1973, although a few have nested since) or that does not migrate or erupt into the province from the north or northwest, however rarely. Thus such birds as Western Sandpiper, Hawk Owl, and Connecticut Warbler, all on the island list, are not considered to be vagrant there. A true vagrant by definition must show displacement to the north or east from its normal breeding or migratory range. Among such vagrants I define birds from range maps in Robbins et al. (1966) as *southern* if they are mapped as not nesting north of Cape Cod, Massachusetts, on the coast, and as *western* if they do not nest west of Lake Michigan. There have been subsequent range changes and cases of extralimital nesting, but the maps are a useful device for separating broad classes of vagrants. The rest are designated as *regional* vagrants, some of which nest as nearby as Maine or New Brunswick. (Black-crowned Night Heron, Common Gallinule, and Wood Thrush have all nested in the province since Tufts', 1973, accounts).

In addition to such birds from the south and west of the province, I include Willow Ptarmagan and Wheatear as clearly displaced *northern* birds. Certain *European* seabirds and shorebirds complete the list.

Table VI Occurrences of vagrant species on Sable Island, as documented in the Account of Species. The geographical origins of the birds are: regional (R), southern (S), western (W), northern (N), and European (E), as defined in the text. Authentication is by photograph (P) or specimen (S). A question mark means that the observation was unaccompanied by a description or is otherwise problematic. A blank denotes a satisfactory sight record.

Species	Geographical origin	Authentication	First record for
Little Shearwater	E	S	N. America
British Storm-Petrel	E	S	N. America
Brown Pelican	S		
Little Blue Heron	S	P,S	
Cattle Egret	S	P	
Great Egret	S	S	
Snowy Egret	S	S	
Louisiana Heron	S	P	
Green Heron	R	P	
Black-crowned Night Heron	R	P	
Yellow-crowned Night Heron	S	P,S	
Glossy Ibis	S	S	
Roseate Spoonbill	S	?	Canada
Willow Ptarmigan	N		
Limpkin	S		
Purple Gallinule	S		
Common Gallinule	R	P,S	
Wilson's Plover	S	P	
Curlew Sandpiper	E		
Upland Sandpiper	R	P,S	Nova Scotia
Marbled Godwit	W	P	
Ruff	E	P	
American Avocet	W		
Wilson's Phalarope	R	P,S	Nova Scotia?
Lesser Black-backed Gull	E		
Mew (Common) Gull	E (prob.)		Nova Scotia
Franklin's Gull	W	P	Nova Scotia
Little Gull	E	P	
Gull-billed Tern	S	?	Nova Scotia
Sooty Tern	S		
Least Tern	S	?	
Royal Tern	S		
Black Tern	R	P,S	
Black Skimmer	S	S	
White-winged Dove	W		Nova Scotia
Yellow-billed Cuckoo	R		
Gray Kingbird	S		
Western Kingbird	W		
Say's Phoebe	W	P	
Rough-winged Swallow	R		Nova Scotia
Cave Swallow	S	S	Canada

Species	Geographical origin	Authentication	First record for
Fish Crow	S		
House Wren	R		
Long-billed Marsh Wren	R		
Brown Thrasher	R	P	
Varied Thrush	W		
Wood Thrush	R	P,S	
Wheatear	N	P	
White-eyed Vireo	S	P	
Yellow-throated Vireo	R		
Warbling Vireo	R		
Prothonotary Warbler	S	P,S	Nova Scotia?
Worm-eating Warbler	R	S	Canada
Blue-winged Warbler	S		
Black-throated Grey Warbler	W		Nova Scotia
Townsend's Warbler	W	P	Nova Scotia
Hermit Warbler	W	P	E. Canada
Cerulean Warbler	S		Nova Scotia
Yellow-throated Warbler	S	P	Nova Scotia
Pine Warbler	R		Nova Scotia?
Prairie Warbler	R	P	
Louisiana Waterthrush	R	P	Nova Scotia
Kentucky Warbler	S	S	Nova Scotia
Yellow-breasted Chat	R	P,S	
Hooded Warbler	S	P,S	
Yellow-headed Blackbird	W	P	Nova Scotia?
Orchard Oriole	R	P,S	
Brewer's Blackbird	W		Nova Scotia
Boat-tailed Grackle	S		Nova Scotia
Scarlet Tanager	R	P,S	
Summer Tanager	S	P,S	
Black-headed Grosbeak	W		
Blue Grosbeak	S		
Painted Bunting	S		Nova Scotia
Indigo Bunting	R	P,S	
Dickcissel	R	P	Nova Scotia
Green-tailed Towhee	W	P	
Rufous-sided Towhee	R	P	
Grasshopper Sparrow	R	S	
Henslow's Sparrow	R	?	Nova Scotia
Seaside Sparrow	R		
Lark Sparrow	R	P,S	Nova Scotia
Field Sparrow	R		Nova Scotia?
Golden-crowned Sparrow	W		Nova Scotia
Chestnut-collared Longspur	W		

The island has also been visited by well-marked western subspecies of the Yellow-rumped Warbler ("Audubon's Warbler"), Dark-eyed Junco ("Oregon Junco"), and White-crowned Sparrow ("Gambel's White-crowned Sparrow").

The regional vagrants are of course the most abundant class of *individual* vagrants on the island, although more species of southern ones have occurred, and a few species of vagrants from remote regions have been more frequently seen than some from more nearby parts. Only the following species of regional vagrants have been seen in Nova Scotia, but not yet on Sable Island: Turkey Vulture, Red-shouldered Hawk, Red-headed Woodpecker, Carolina Wren, Short-billed Marsh Wren, Golden-winged Warbler, and Cardinal (which has recently nested in the province). The 2 raptors are probably capable of avoiding extreme offshore displacement and the Red-headed Woodpecker, Carolina Wren, and Cardinal probably seldom make major migratory movements of the sort that might carry them to Sable Island.

Among the birds designated as southern, most herons and their relatives are so regular in their northward movements that they might not properly be considered to be vagrant. Similarly, the Marbled Godwit and Wilson's Phalarope may routinely come to the east coast farther south, although their breeding ranges, prior to 1971, and usual routes qualify them as western.

Most southern and western landbirds in Table VI are exceedingly displaced and probably seldom regain their normal ranges. Elsewhere I have analysed the incidence of vagrant landbirds on Sable Island, as well as on Seal Island, Yarmouth Co., and Brier Island, Digby Co., in comparison with other localities in eastern North America (McLaren 1981). The abundance, or diversity, of western migrants is higher in Nova Scotia than on islands off North Carolina and Florida, and more comparable vagrant species have been seen on the Nova Scotian islands than in any other locality of similar size in eastern North America. The convergence of continental windstreams from the south and west on Nova Scotia during migration seasons may play a role in this vagrancy. However, within Nova Scotia the relative abundance of western and southern vagrants is higher on Sable Island than on Seal Island or Brier Island, both of which are much closer to the mainland. It appears that, although regional species tend to avoid Sable Island (see previous section), birds from remote regions do not, and may indeed be attracted to refuge from a large sweep of ocean. From this analysis and from selected records of arrivals in relation to weather patterns, I concluded (McLaren 1981) that navigational error by vagrants is paramount in bringing them to Sable Island. Southern and southwestern species may "overshoot" their normal destinations in spring. Some western species may come by "mirror-image misorientation", whereby a normal tendency to migrate northwest from Mexico is expressed as a misorientation northeastward; support for this comes from analysis of records of western *Dendroica* in the east (McLaren 1981). Southern birds may show reverse migration in autumn, or they, along with western species, may show tendencies to fly downwind, which may lead them ultimately to Nova Scotia and offshore to Sable Island.

Given the occurrence of such unprecedented species as Little Shearwater, Cave Swallow, and Hermit Warbler, prediction of future candidates for the island's list would be idle. However, McLaren (1981) lists 14 southern and western species that have been found on Brier or Seal Island, but not yet on Sable Island, and there are 9 more on the Nova Scotian list. In addition, about 24 vagrant seabirds, waterfowl, herons (and relatives), rallids, and shorebirds have been seen elsewhere in the province, but not yet on Sable Island. Any of them could occur in future, and quite probably some totally new ones as well.

Unseasonable Records

Many records of birds out of their normal seasons add to the unusual flavor given by the vagrant species. These are reviewed briefly here under several categories.

Numbers of early dates for spring migrants are given in the Account of Species. Most are of scattered individuals, but some occurred in groups, suggesting that meteorological conditions played a role. A striking example was the appearance in early April 1972 of a number of species of shorebirds, including a vagrant Wilson's Plover and a probable "western" Willet (Table VII). During the first days of April a stalled front extended the length of the coast of the eastern United States, with strong southwesterly flow outside it. Shorebirds coming north to the southeastern states may have been prevented from making a landfall by unsettled coastal weather, and impelled too far north by the winds. Also of interest were mid-April occurrences of Prothonotary and Blue-winged Warblers, accompanied respectively by an Ovenbird and Wilson's Warbler, and by a Yellow Warbler. Both occurrences were accompanied by slack, high-pressure conditions in the southeastern and eastern states, although there were offshore winds farther north. It appears that these early birds had "voluntarily" flown beyond their normal limits at this season because of excellent conditions for northward migration.

A number of regional migrants, especially those that nest in Newfoundland, routinely lingered through June. A wide variety of species also appeared in early July, suggesting a widespread pattern of wandering by nonbreeders other than the well known shorebird examples. "Winter" finches were particularly common in summer 1968, prior to an "unprecedented" (Plunkett 1969) eruption southward next winter. There were also odd cases of boreal or subarctic birds in summer: Water Pipits in early August 1965 and 1968; a Bohemian Waxwing on 29 June 1968, presaging an invasion in the province next winter; Common Redpolls through July 1968; a Snow Bunting in late July 1902; numbers of summer Snowy Owls; and a Hawk Owl on 10 June 1902. In general, there were gaps between the

Table VII Unusually early occurrences of shorebirds (all single individuals) in April 1972 (none included in migration table, Table III).

Species	Date
Semipalmated Plover	11 Apr.
Wilson's Plover†	2 Apr.*
Whimbrel	6-7 Apr.*
Greater Yellowlegs	6-7 Apr.
Lesser Yellowlegs	3,6 Apr.*
Willet°	2 Apr.*
Red Knot	2 Apr.*
Least Sandpiper	11 Apr.*
Pectoral Sandpiper	7 Apr.*
Short-billed Dowitcher	8 Apr.*

* Earliest spring record for the province.
† Third provincial record, first well authenticated (Fig 6).
° Probably western race (see text, Fig 7)

occurrence of such summer stragglers on the island and their appearance as normal fall migrants later in the summer.

Late autumn occurrences are common on the island, and some postdate latest records from other Nova Scotian localities. For some boreal species the frequency of late records implies a normal pattern. For example, there were Gray-cheeked or Swainson's Thrushes during November in 7 years and Blackpoll Warblers during mid-November to mid-December in 3 years of 1967-1979. Some late records of other regional species may represent returns to the region from the south, along with reverse-migrating vagrants.

Winter records imply that there is more movement of birds at this season than might have been expected. Perhaps least surprising are the records of seabirds that normally winter farther south, as these are readily caught in storms. These include storm petrels (probably Leach's), a Double-crested Cormorant, a Laughing Gull, and 2 sightings of Sabine's Gulls. There are subsequent winter sightings of these species from elsewhere in Nova Scotia. The list of "half-hardy" shorebirds and landbirds arriving in winter implies that there is some potential for unseasonable emigration by these birds from deteriorating habitats on the mainland. Such records are given for Great Blue Heron, Killdeer, Common Snipe, Belted Kingfisher, Common Flicker, Northern Mockingbird, American Robin, Yellow-rumped Warbler, Eastern Meadowlark, Rusty Blackbird, and Common Grackle. More surprising are records of birds that do not winter in the region: a Barn Swallow, a Swainson's Thrush, and a Blackpoll Warbler have all turned up in midwinter on the island.

Historical Changes

Of prehistoric avifauna nothing is known, but the greatly enlarged landmass during and after the last great advance of Pleistocene ice (see sketch map in McLaren 1972) must have supported more breeding birds, perhaps including forest species. Since its discovery, Sable Island has always offered the same limited kinds of environments described under Bird Habitats and Bird Finding. However, there has been a considerable loss of vegetated terrain (sequential maps in McLaren 1972) and one great change in the virtual disappearance of Wallace Lake, once an extensive lagoon, with a warm-water fauna of such species as oysters (*Ostrea virginica*) and bay scallops (*Pecten irradians sablensis*), now extinct on the island (Clarke et al. 1967). This big lagoon, with its shallows, saltmarshes, and freshwater reaches, may well have offered habitat for nesting species not found today. Thus statements that Osprey, Common Snipe, and perhaps even Gull-billed Tern nested in the last century are plausible in the light of such environmental changes.

The great restriction in the lagoon habitat of Wallace Lake has certainly had an effect on the occurrence and abundance of waterfowl on the island. Whereas at the turn of the century Greater Scaup, Oldsquaw, and the scoters were common in winter, they are rather infrequently sighted today. There are also references in the diaries (in Nova Scotia Archives) of island superintendents to the hunting of ducks in fall and winter on Wallace Lake.

Other changes in the avifauna of the island reflect the fortunes of bird populations on a wider scale. The breeding terns have undergone catastrophic decline, while gulls have begun to nest and have become abundant in this century. Whereas the Bouteilliers collected or noted only a Great Egret, a Yellow-crowned Night Heron, and a probable Little Blue Heron during their years of observation, southern herons and their relatives are quite regular today; this no doubt reflects recovery from 19th century overkilling. The shorebirds were also subjected to heavy hunting in those days, and it is perhaps of interest that the species most frequently reported by them were the small White-rumped Sandpiper and the wary Greater Yellowlegs (Table IV), rather than such gamebirds as Black-bellied and Golden Plovers.

Elsewhere (McLaren 1981) I have suggested that there have been changes in the incidence of vagrancy by certain landbirds since the turn of the century. The Bouteilliers recorded 14 species (some perhaps doubtful) that I have classed as vagrant, most of them quite uncommon today (fewer than 10 individuals during 1967-1979). The most abundant vagrant species in recent years (>20 individuals 1967-1979) have been, in order, Dickcissel, Prairie Warbler, Rufous-sided Towhee, Brown Thrasher, Yellow-breasted Chat, Indigo Bunting, and Scarlet Tanager. Of these, the Bouteilliers reported or collected 1 Indigo Bunting and 3 Dickcissels. It would have been hard for them to overlook some of the others, most quite conspicuous, if they were as common then as today. These birds have shown range expansions in recent years, and all except the Dickcissel and tanager have probably benefited from the proliferation of second growth and scrub in human-disturbed habitats.

Account of Species

Here details are given on the 325 species that have been reported on Sable Island up to the end of 1979. For many, the dates and numbers in Tables III and IV summarize much that needs be said, except for short comments on extraseasonal occurrences and other observations of possible interest. Data on occurrences are more comprehensive for species that have been seen less frequently—arbitrarily those that have occurred in fewer than 5 times in 5 different springs or autumns between 1967 and 1979.

After 236 species names, confirmation of the bird's presence on the island is given in parentheses. "P" indicates that the bird has been photographed, and the color slide is on file at the National Museum of Natural Sciences, Ottawa. The various museums where specimens from the island are deposited are: American Museum of Natural History, New York (AMNH); National Museum of Natural Sciences, Ottawa (NMC); Nova Scotia Museum of Science, Halifax (NSMS); the Royal Ontario Museum, Toronto (ROM); the Science Museum at Springfield, MA. (SMS); and the museum at l'Université de Montréal (UM).

I have accepted sight records made in recent years based on my knowledge of the observers and on written descriptions of some rare or "difficult" species. I give certain of the descriptions and circumstances for some such species. The following have supplied extensive notes on which the migration table (Table III) and many of the following accounts are based (initials given for those used as authorities for more unusual records): Christel and Norman Bell (CB, NB), Jean Boulva (JB), Jean Burton (JBu), Davis W. Finch (DWF), E.H. Miller (EHM), Eric L. Mills (ELM), Alban A. Richard (AR), Howard Ross (HR), Wayne Stobo (WS), and Dan Welsh (DW). Notes for shorter periods were supplied by Eleanor Androschuk, R.G.B. Brown, Donald Gunn, Robert Lamberton and Bruce Mactavish, and a few interesting records were supplied by other individuals, as named in the accounts.

In making use of the many contributions by the Bouteilliers, I give formal references to their published notes (in bibliography), and give the year of sighting for the unpublished manuscript lists, as given in Table I. The interview of James Bouteillier on birds of the island, by Harry Piers in 1902, is referred to throughout as "Piers MS".

In considering the seasonal status of species in comparison with other Nova Scotian records up to the end of 1979, I have referred to Tufts (1973) and to the *Nova Scotia Bird Society Newsletter*, and the journal *American Birds* (formerly *Audubon Field Notes*).

Common Loon *Gavia immer* (SMS)

The 6 sightings since 1965 include 1 each from February, May, June, and October, and 2 from September. It was thought to be "rare" in 1901 (Piers MS).

Red-throated Loon *Gavia stellata* (SMS)

One long-dead in June 1967 and 3 near shore on 17 October 1975 are our only recent records. The specimen is dated 23 November 1900, and Bouteillier (1908b) reported another.

Red-necked Grebe *Podiceps grisegena* (P)

An adult was found "grounded" on 18 August 1965, another was unseasonable on a pond on 3 July 1967 (CB), and a corpse was found in spring 1970.

Pied-billed Grebe *Podilymbus podiceps* (P; AMNH)

Eight individuals on ponds during 3 recent autumns were seen as early as 13 September 1973 and as late as 14 December 1969. Specimens taken on 14 September and 30 December 1901 are additional to those reported in Table IV.

Northern Fulmar *Fulmarus glacialis* (AMNH, NMC, NSMS)

Fulmars are regular in surrounding waters (Brown et al. 1975). In recent years they have been seen from the island or found recently dead on beaches during every month, most frequently in May-June and September. An estimated 650 came ashore in 'Arrow" oil in late winter 1970, mostly *F. g. glacialis* from Greenland or eastern Atlantic colonies (Brown et al. 1973). The specimen in the Dwight collection is also labelled as this race.

Cory's Shearwater *Puffinus diomedea* (ROM)

This species is commonest near the island (Fig 3) in July (Brown et al. 1975). First sightings from the island were in 1968, and about 25 have been seen since, as early in the summer as 19 June 1979 and as late as 11 September 1974.

Greater Shearwater *Puffinus gravis* (AMNH, NMC, NSMS, ROM, SMS)

Shearwaters are readily seen from the island's tips in summer, especially when winds are easterly. The earliest spring record was of a freshly dead bird on 23 May 1971 and the latest was found dying on the beach on 2 December 1970. When shearwaters were present in large numbers in early summer (i.e., 5000 or more estimated), this species was generally outnumbered (ratios of 3:1 to 20:1) by Sooty Shearwaters. However, an estimated 14,000 Greater and only a few Sooty Shearwaters passed the island on 5 June 1978 (P. Vickery). The largest count of Greaters in late summer was 650 on 22 August 1977.

Sooty Shearwater *Puffinus griseus* (AMNH, NSMS, SMS)

Numbers were greatest in early summer, varying with wind and weather. The earliest seen from the island was a bird on 20 May 1977. However, S.W. Gorham (in litt.) saw 3 very near the island on 9 May 1961. The latest were 3 on 26 November 1969, later than they normally are found in the region (Brown et al. 1975). Estimates have been made of 1000-3000 birds passing the island during periods of a few hours in some years, but counts made after early August never exceeded 50.

Little Shearwater *Puffinus assimilis* (AMNH)

A specimen found dead on 1 September 1896 (Dwight 1897) is the only Canadian record. It is of the *baroli* (Madeira-Azores) race.

Manx Shearwater *Puffinus puffinus* (NMC)

This species, which has recently colonized islands off southern Newfoundland, was evidently first seen off Nova Scotia in 1963 and is now regular in summer (Brown et al. 1975). The first from Sable Island was seen on 3 July 1966 (CB, NB). It has been seen regularly in recent years, as early in the season as 28 May 1974 and as late as 19 September 1974. During July 1978 it was the commonest shearwater around the island on calm days, with 125 along the south beach on 24 July. A corpse found on 23 June 1970 had been banded as a nestling in the previous summer on Skokholm Island, Wales.

Leach's Storm-Petrel *Oceanodroma leucorhoa* (P; AMNH, ROM, SMS, UM)

There were scattered sightings of the species as early as 18 May 1972 and as late as 27 October 1968. Very late fall or winter sightings of storm petrels, presumably this species, were 60 on 30 November 1964, and "flocks" on 3 January and 23 March 1967 (CB, NB). These, along with 8 oiled Leach's in "Arrow" oil on 1 March 1970 (Brown et al. 1973) are somewhat unexpected (cf. Brown et al. 1975). A dead bird on 2 July 1968 had been banded on 17 July 1965 on Kent Island, N.B. Early reports of "Storm Petrels" (meaning *Hydrobates pelagicus*) nesting on Sable Island (e.g. Bent 1922) would possibly be referable to *O. leucorhoa*. However, James Bouteillier (Piers MS) did not mention breeding, and Dwight (1895) thought that birds taken by him had wandered from the Nova Scotian coast. Certainly it does not now nest, although there are places where the soil might be adequate.

British Storm-Petrel *Hydrobates pelagicus* (NMC)

One that blundered into a mist net, set by JBu for shorebird banding, on 10 August 1970 was a first specimen for North America, earlier records being suspect (McNeil & Burton 1971).

Wilson's Storm-Petrel *Oceanites oceanicus*

An early individual was identified on 2 May 1971 (JB). The few sightings in recent years between June and September do not reflect its abundance near the island (Brown et al. 1975).

Brown Pelican *Pelecanus occidentalis*

A bird sitting in a shallow pond on the beach on 26 June 1963 was approached very closely before it flew (CB, NB). Almost all the 8 or so records in the province are for late spring or early summer.

Northern Gannet *Morus bassanus* (P)

This species is more regular around the island than maps in Brown et al (1975) might suggest. The earliest was an oiled bird on 1 March 1970 and the latest were 3 on 29 December 1969. Hundreds passed the island on some days in late March and early April 1972, and they have probably been overlooked during migration in other years. Smaller numbers have been seen during every month between April and November, especially immature birds in summer. A recently dead bird on 16 September 1964 had been banded a month earlier on the nest at Ile Bonaventure, Qué.

Great Cormorant *Phalacrocorax carbo* (P)

Since 1977 about 23 individuals have been seen in spring, as early as 24 April 1977 and as late as 28 June 1977. Ten individuals in autumn since 1968 have been seen as early as 11 September 1974 and as late as 4 November 1968.

Double-crested Cormorant *Phalacrocorax auritus*

The species was regular in small numbers in spring, as early as 28 April (median

30 May) and as late as 16 June (median 2 June), thus much later on average than on the mainland. They rarely lingered, and were still presumably migrating northward. Three between 31 August and 24 September 1978 were the only fall sightings. An adult closely observed on 3 February 1965 (CB, NB) was a first winter record for the province, although there have been several since. A record of an unspecified cormorant on 1 January 1907 Bouteillier (1908a) was, on the original list, noted as "not . . . a whole bird", and may have been a long-dead corpse.

Great Blue Heron *Ardea herodias* (P)

Most herons of this and other species are seen around ponds near West Light, where there are only mummichog (*Fundulus heteroclitus*), sticklebacks (3 species), and perhaps a few eels (*Anguilla rostrata*) as food (Garside 1969). Numbers of individuals of various heron species have been found dead on the island, probably of exhaustion and subsequent starvation. Great Blue Herons occurred every year since 1966, but not always in both spring and fall (Table III). One on 14 January and another on 14 February 1969 (not in Table III) may have been attempting to winter in the region. The bird on 16 March 1973 can be assumed to have been an early migrant; it died on 22 March. The earliest fall record was on 5 August 1904 (Table IV).

Great Egret *Casmerodius albus* (AMNH)

There were 3 recent sightings of this vagrant: individuals on 28 May 1966 (CB, NB), during 7-25 May 1968 (CB, IM, et al), and between 30 June and 4 July 1977 (HR et al.). The male in the Dwight collection was taken on 10 April 1897.

Snowy Egret *Egretta thula* (NMC)

This was the most frequent vagrant heron in recent springs (Table III). Two between 24 March and 10 April 1977 and another on 29 March 1979 (all AR) were unusually early (included in Table III). A bird evidently freshly killed by gulls on 26 December 1974 (EHM) was very late (not in Table III). A Snowy Egret mentioned by Richard Bouteillier (Piers MS) apparently refers to the specimen of Great Egret in the Dwight collection.

Little Blue Heron *Florida caerulea* (P; NMC)

This vagrant has been most regular in fall (Table III). One on 20 June 1965 (CB) was later than any of the more recent spring birds (cf. Table III). All but 2 of the fall birds were adult or near-adult. James Bouteillier's "Blue Heron" of 1 May 1902 was evidently (Piers MS) a specimen of this smaller species which was not sent to Dwight.

Lousiana Heron *Hydranassa tricolor* (P)

One seen on 3 August 1972 (DW) and another on 18-20 May 1979 (B. Mactavish) are among about a dozen records from the province.

Cattle Egret *Bubulcus ibis* (P)

Single birds were seen on 12 June 1965, 1 May 1967, 15-22 May 1968 (all CB, NB), 7 July 1977 (HR), 17 November 1975 (AR), and 10 September 1979 (AR et al.). Old corpses were found in July 1969 and 1970.

Green Heron *Butorides striatus* (P)

This vagrant was quite regular in spring, less so in fall (Table III). often on smaller, isolated ponds.

Black-crowned Night Heron *Nycticorax nycticorax* (P)

Three have been sighted in spring (26 May 1968, 21 March to 11 April 1971, 27 May 1975) and 3 in fall (2 on 10 October 1974, 1 on 16 October 1975). Although it

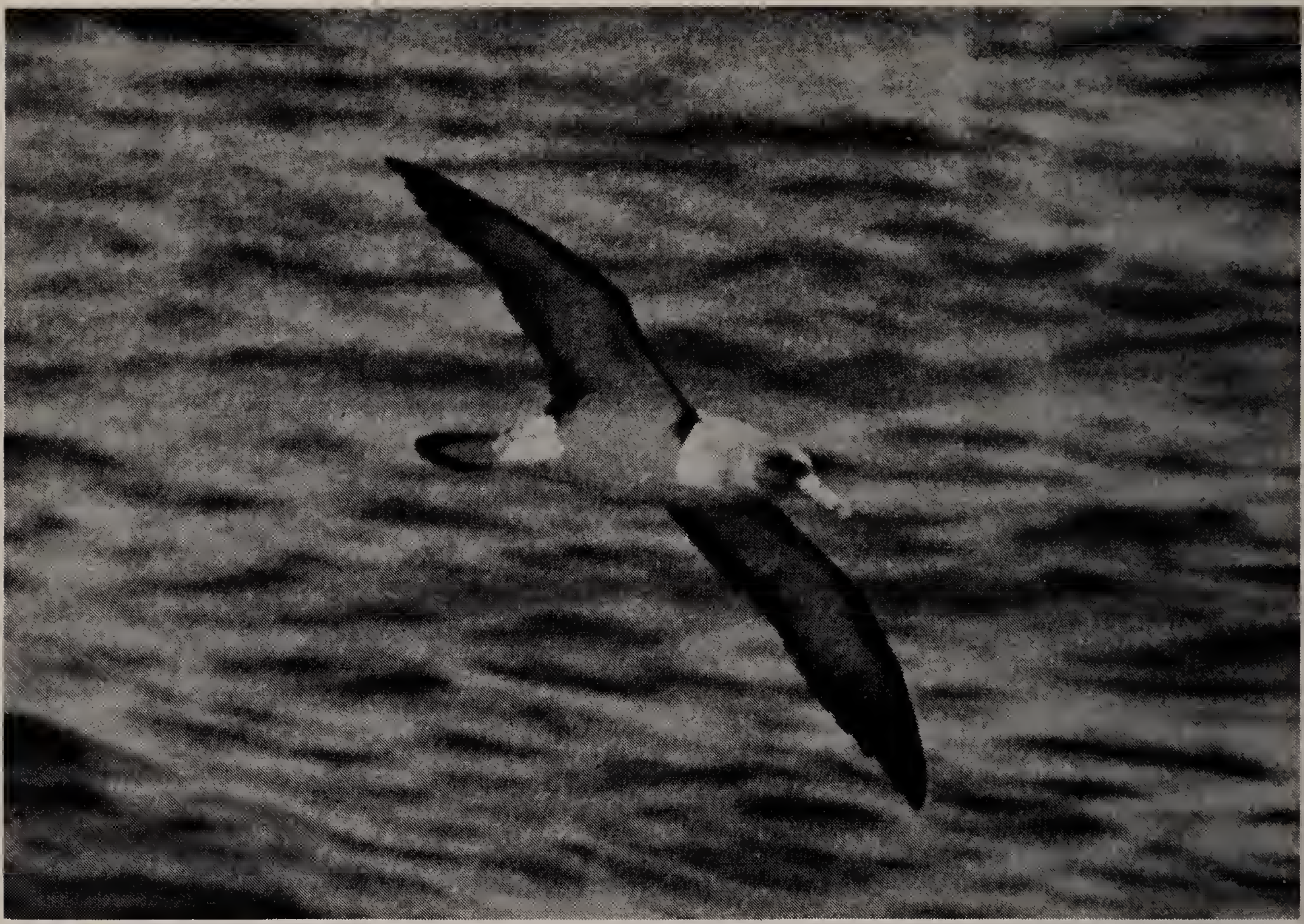

Fig 3 A Cory's Shearwater near the northern limit of its range, over Sable Island Bank. (Photo: July 1968, P. Germain.)

Fig 4 A Yellow-crowned Night Heron, the most regular of the vagrant herons, on the rubble of the Old No. 3 Station. (Photo: 25 August 1977, I. McLaren)

has nested recently in Nova Scotia, it is thus much less frequent on the island than are some other vagrant herons.

Yellow-crowned Night Heron *Nyctanassa violacea* (P; AMNH, NMC)
Most recent records (Table III) were immature birds (e.g. Fig 4). Bouteillier's (1905) specimen on 13 April 1904 is the only spring record.

Least Bittern *Ixobrychus exilis*
Four individuals of this rare species have occurred in recent years: on 11 July 1966, 1 June 1969, 1 November 1969 (all CB, NB), and 12 September 1974 (IM, B. Mactavish). Bouteillier (1908a; 1908b) reported individuals on 9 October 1906 and 13 May 1907, and 2 or 3 occurred "about 3 years" before 1901 (Piers MS).

American Bittern *Botaurus lentiginosus* (P)
Bitterns have been quite regular in fall, but not in spring (Table III). A late bird was seen on 4 December 1968 (CB; not in Table III). It was also regular in fall at the turn of the century, when 1 on 5 December 1903 (not in Table IV) was unusually late.

Glossy Ibis *Plegadis falcinellus* (P; NMC)
This vagrant has been occasional in spring since 1968 (Table III).

Roseate Spoonbill *Ajaia ajaja*
In a conversation some years ago with Richard Ryan (in litt. to IM, 23 May 1980), the late J.J. Elliot told of seeing a Roseate Spoonbill on Sable Island during his visit between 30 July and 3 August 1948. Evidently Elliot was loath to publish this sighting (e.g. in Elliot 1956), as it was unsupported by specimen or photograph, although it seems unlikely that such a species could have been mistakenly identified by an observer of Elliot's experience. The species has not been reported in Canada, and must clearly remain at best "hypothetical" on this evidence.

Canada Goose *Branta canadensis* (P)
Small numbers stopped on the island in spring and fall most years (Table III). Six wintered in 1976-77 and were last seen on 5 April (not in Table III). A very large group of about 1000 passed southward over the island on 6 September 1975 (not in Table III).

Brant *Branta bernicla*
One was listed by Richard Bouteillier on 7 November 1908, but none has been seen in recent years.

Snow Goose *Chen caerulescens*
According to Gilpin (1880) 2 young "Barnacle Geese" sent to him from Sable Island resembled 2 young geese shot in Halifax, later determined by Downs (1888) as Snow Geese. Gilpin's description of the Sable Island birds fits Snow Goose, but not Barnacle Goose.

Mallard *Anas platyrhynchos*
Mallards were occasional in recent years in spring and fall (Table III). The "6 or 7" seen by Bouteillier (1908a) on 1 November 1906 probably antedated introduced stock in the region. An apparent Mallard X Black Duck hybrid was noted on 3 June 1969 (JB).

Black Duck *Anas rubripes* (P; AMNH)
In recent times the Black Duck (Fig 5) has occurred at all seasons, augmented by larger numbers of migrants (counts up to 300 on the island) in fall. It was sometimes common in winter, with counts of 40-100 reported at times during the

open winter of 1968-69. It left during hard weather in other winters, as none was found during extensive travels in late February 1971 and January 1972. Estimates of the resident adult population of the whole island in May or early June of recent years ranged between 12 and 30 individuals. As a commonplace species it was rarely listed by the Bouteilliers, but evidently occurred in flocks of up to 300-400 in winter (Piers MS). The earliest eggs in recent years were found on 1 May 1977, but diaries of 19th-century superintendents record eggs on 20 April 1833 and on 22 April 1848 (Nova Scotia Archives). Complete clutches in recent years (with number of nests in parentheses) were 6(1), 7(1), 8(12), 9(7), 10(9), and 11(2). First new ducklings were reported during 10 seasons between 16 May and 9 June (median 24 May). An incomplete (?) clutch of 3 incubated eggs was found as late as 3 July 1972, and a new brood as late as 23 July 1971. Despite gull predation, production of flying young is quite successful. Four clutches taken for captive rearing programs of the United States Fish and Wildlife Service in late May 1977 hatched in Maryland, but the young died of egg-transmitted *Salmonella* (A.R. Lock, Canadian Wildlife Service, in verb.). Yet 9 healthy broods were found that year on the island during early June. A long-dead bird in May 1970 had been banded near Debert, N.S., on 9 December 1969.

Northern Pintail *Anas acuta* (P)

The Pintail was a regular migrant (Table III), and also nested in several years. Six half-grown young were seen on 6 July 1967, a brood of 8 was fledged in 1975, and 8 of 9 hatched were fledged in 1976, all on ponds near West Light. In 1977 up to 6 males and 7 females in May led to 5 discovered nests during 21-26 May (clutches 7, 8, 9, 9, 12) and a replacement clutch (incomplete?) with 5 eggs on 9 June. First young appeared on 7 June and at least 14 full-grown young were about in later summer. In 1978 numbers dwindled, and only a brood of 5 was noted. In 1979 a resident pair was present, but no evident nesting occurred. Richard Bouteillier (Piers MS) thought they were 'uncommon in winter", and they otherwise were mentioned only tentatively (Bouteillier 1901).

Gadwall *Anas strepera* (P)

The only record is of a pair that spent the day on ponds near West Light on 12 June 1973 (DWF, IM).

Green-winged Teal *Anas crecca* (P; SMS)

This teal was generally scarce in spring, but at times common in autumn (Table III), with large counts of 80 on 3-5 November 1968 and 62 on 13 September 1972. It nests irregularly. Nests were found on 17 May 1976 (10 eggs) and in late May 1979 (5 & 8 eggs), and broods were noted on 6 July 1967 (6 new ducklings), mid-August 1977 (4 large young), and 15 July 1978 (2 small young). In other years birds lingered in June, but neither nests nor broods were found. There are no references to it in earlier publications, and evidently "only a few flocks of half-dozen a winter" occurred 80 years ago (Piers MS).

American Wigeon *Anas americana* (P)

There are only a few modern sightings: 3 during 26-29 November 1970, 2 on 24 October 1973, 1 on 2 May 1974, a pair during 1-3 May 1976, and 1 on 6-9 September 1978. Among 3 early reports (Table IV) they were rated as "numerous" on 28 October 1905 (Bouteillier 1906).

Blue-winged Teal *Anas discors* (P)

This teal is a regular migrant (Table III), with flocks of 30-50 reported some years in September. Pairs, with an extra male at times, could generally be found into June, but nesting was only thrice confirmed: Erskine (1953) noted a female

Fig 5 A Black Duck nesting in the disappearing rose garden at Old Main Station. (Photo: 23 May 1977, I. McLaren.)

Fig 6 Nova Scotia's first well-authenticated Wilson's Plover, exceptionally early near the west tip of the island in spring. (Photo: 2 April 1972, I. McLaren.)

with young in late August 1953; 8 newly hatched young were seen on 30 June 1971; and a female hatched a clutch of 5 eggs on 21 June 1975. The species was not common in earlier times (Table IV).

Northern Shoveler *Anas clypeata*

Richard Bouteillier (Piers MS) reported "only one—a couple of years ago [i.e., prior to 1901] in spring." It is to be expected today in view of its recent increase in Nova Scotia.

Wood Duck *Aix sponsa* (NMC)

This species, uncommon in Nova Scotia, was occasional in spring and rare in fall (Table III). Also, long-dead birds were found in spring 1969 and 1976.

Canvasback *Aythya valisineria* (NMC)

A desiccated corpse of a female or immature bird was found in late May 1974.

Redhead *Aythya americana*

Richard Bouteillier (Piers MS) reported it as "rare; towards spring" 80 years ago, when there was a remnant east-coast population (e.g., see Tufts 1973).

Ring-necked Duck *Aythya collaris* (P)

It was occasional in spring and fall (Table III). Bouteillier (1901) reported it once: 5 on 20 October 1901.

Greater Scaup *Aythya marila* (P; AMNH, ROM)

The only recent records were: 1 on 17 September 1964, a pair between 28 March and 16 April 1972, a flock of 15 during 12-15 November 1977, and 2 during 16-18 October 1978. The Bouteilliers, on the other hand, reported them regularly in fall (Table IV), sometimes as "numerous". The beak and wing catalogued in the Dwight collection are missing.

Lesser Scaup *Aythya affinis*

Single drakes were closely observed on 3 August 1963 and 17-18 August 1968 (both CB), and on 28 May 1977 (IM). It was rated as "uncommon" in winter by Richard Bouteillier (Piers MS).

Common Goldeneye *Bucephala clangula*

There are only 3 recent sightings, 12 on 5 November 1968, 1 on 24 May 1978, and 20 on 12 December 1979. These augment the few reports from earlier times (Table IV), although Richard Bouteillier (Piers MS) thought them "common" in winter.

Barrow's Goldeneye *Bucephala islandica*

A tame pair spent the day on ponds near the Meteorological Station on 2 April 1971 (DW), constituting the only island record.

Bufflehead *Bucephala albeola*

The only recent records were of 2 female or immature birds on 28-30 November 1970 and a male on 7 April 1972. The Bouteilliers listed them more often (Table IV), and they were thought to be "uncommon [in] winter and towards spring" (Piers MS).

Oldsquaw *Clangula hyemalis* (P; AMNH)

The only recent sightings were of 20 offshore on 4 November 1968 and of a female on ponds near West Light on 6-9 April 1972. An estimated 30 corpses came ashore in "Arrow" oil in late winter 1970 (Brown et al. 1973). Bouteillier (1908a) listed 2 on the unusual date of 26 June 1906, and they were frequent in fall (Table IV), generally "in no.". Richard Bouteillier (Piers MS) also stressed that they were "very abundant" between September and April prior to 1901.

Harlequin Duck *Histrionicus histrionicus*
Five frequented the surf zone off the north beach near West Light between 28 September and 3 October 1977 (AR).

Common Eider *Somateria mollissima* (P)
Lone females were seen on 31 March 1972 (feeding near a wreck) and on 13-15 November (on a flooded beach), and a flock of ca. 100 was present beyond the surf on 1-2 February 1978. The Bouteilliers did not record them.

White-winged Scoter *Melanitta deglandi*
The only recent records were of 2 on 9 September 1963, 5 on 29 September 1968, 5 stragglers on 11 July 1969 (all these on ponds or Wallace Lake), and an offshore flock of ca. 400 on 20 November 1970. Evidently it was "the most common scoter" at the turn of the century (Piers MS) and was listed regularly (Table IV).

Surf Scoter *Melanitta perspicillata*
Our only recent reports were of a single male on a pond on 5 June 1963, an offshore flock on 24 April 1968, a male on Wallace Lake on 20 June 1973, and 4 offshore on 29 August 1978. The Bouteilliers did not report the species on annual lists, but evidently it was "common" in winter (Piers MS).

Black Scoter *Melanitta nigra*
An unseasonable male was seen on Wallace Lake on 14 July 1965. The Bouteilliers did not list it, but it was apparently "common" in winter (Piers MS).

Ruddy Duck *Oxyura jamaicensis* (AMNH)
A male on 25 June 1971 was unseasonable (IM, WS). At least 3 were present in late November and early December 1974, and a male was seen on 4 April 1975. The Bouteilliers did not include it on annual lists, but evidently it was "uncommon" in winter (Piers MS). The specimen catalogued in the Dwight collection, as "head and beak only, winter 1896-97", could not be found.

Hooded Merganser *Mergus cucullatus*
The only record is of 3 on 5 November 1978 (AR).

Common Merganser *Mergus merganser*
The few records are: a female on 6 April 1972, a male during 22-25 April 1976, 2 males on 15-19 October 1978, and a pair on 10-24 March 1979.

Red-breasted Merganser *Mergus serrator* (P; AMNH, ROM)
This species nests on the island, its numbers increasing in fall, with flocks of up to 150 in August-September, often as molting groups on the remnants of Wallace Lake. It winters on the island, with counts as high as 75 on 18 February 1971 and 175 on 21 January 1972, made on the whole island. Island counts of adults (with some subadults courting and perhaps breeding) during late May and June in recent years ranged between 20 and 60. Full clutch sizes (with number of nests in parentheses) were: 8(2), 9(2), 10(4), 11(1), and 13(2). The earliest nest found was on 1 June 1970; however, the earliest brood had 6 hatchlings on 2 June 1968. Most nests were found later and other first broods of the season occurred during 3-21 July (median 14 July) in 5 years. The breeding success of mergansers seemed lower than that of the Black Duck, but a few full-grown broods and flying young were seen in late August in some years. It was recognized as breeding by Gilpin (1858) and Vieth (1907) in the mid-19th century.

Goshawk *Accipiter gentilis*

Fully 5 of the fall birds in Table III occurred in 1967, and were preceded by an early adult on 24 July (not in Table III). The Bouteilliers reported "various" hawks (unspecified) in several years, including a "chicken hawk" on 10 May 1902, and Richard Bouteillier did "not know the hawks sufficiently to name all that occur on the island" (Piers MS).

Sharp-shinned Hawk *Accipiter striatus* (NMC)

In recent years 3 have occurred in spring (30 May 1977, during 19-24 May and on 3 June 1978) and 4 in fall (28 September - 1 October 1970, 17 October 1975, 16 September 1977, and 25 August - 13 September 1978). Dead birds were found in mid-May 1977 and early December 1970.

Red-tailed Hawk *Buteo jamaicensis*

Individuals perched on towers on 8 August 1965 and 22 October 1969.

Broad-winged Hawk *Buteo platypterus*

A very tame adult occurred on 17 August 1966, another was found recently dead on 2 June 1969, and a third was seen on 16 October 1978.

Rough-legged Hawk *Buteo lagopus*

This was the most regular *Buteo*, especially in fall migration, once quite early (Table III). Two were seen at times through the winter of 1977-78, although there are no rodents available on the island.

Bald Eagle *Haliaeetus leucocephalus*

Richard Bouteillier (Piers MS) stated that "a couple" were obtained some years before 1901.

Marsh Hawk *Circus cyaneus* (NMC)

The bird was rare in spring and uncommon in fall (Table III). The only older report is of a bird rather tentatively identified in the summer of 1866 (Vieth 1907).

Osprey *Pandion haliaetus* (P)

Single birds passed the island with some regularity in spring, but it was seen rarely in fall (Table III). One on 8 July 1971 was presumably not a normal migrant (not in Table III). The Bouteilliers reported a few in autumn (Table IV), and it was noted (Piers MS) as uncommon and nonbreeding. However, it is possible that it nested in the dunes in earlier times, as it still does in some parts of its range, for Vieth (1907) wrote from his visit in summer 1866 that "fish hawks (*Falco halioetus* of Lin) are common." The great expanse of Wallace Lake would have offered good fishing then.

Peregrine Falcon *Falco peregrinus*

Spring birds were on 13 May 1973, 28 May 1976, and 4-5 May 1978. Fall migrants occurred on 14 October 1971, 16 October 1975, and 29 September 1976. A winter bird was seen well on 7 February 1978 (AR).

Merlin *Falco columbarius* (P)

Merlins appeared in every month from March to December (Table III). One between 30 June and 3 July 1969 and another on 28 June 1971 were between seasons, and another stayed from mid-October 1968 until at least 25 February 1969 (none of these in Table III).

American Kestrel *Falco sparverius* (P)

Kestrels are the most regular raptor on the island (Table III). Since 1967 most have occurred in May (16 individuals) and September (21, including 9 during 25-29 September 1970). A winter bird occurred between 21 January and 25 February

1974 (not in Table III). Bouteillier (1908a) reported an early fall migrant on 4 August 1906.

Willow Ptarmigan *Lagopus lagopus*

An extraordinary ptarmigan perched on a fence near West Light on 12 August 1966, and was studied within 3 m by CB and NB. Although they hesitated to identify the species as other than a ptarmigan at the time of sighting, their written description indicates a male Willow Ptarmigan in summer dress. Presumably it came from Newfoundland, as it antedates introductions of the species to Scatari Island, off Cape Breton Island.

Bobwhite *Colinus virginianus*

An individual on 26-27 July 1966 (CB, NB, E. Androschuk) presents a puzzle. There is no record of the species having been introduced with the pheasants in 1961 (see next species), and no Bobwhites had been seen by CB during 1963-1965. The possibility of its arriving on its own is, however, very remote.

Ring-necked Pheasant *Phasianus colchicus*

About 25 pheasants introduced on private initiative in 1961 remained scarce until 1964, when they began to increase in numbers with winter feeding. They became extinct in winter 1970-1971 with the cessation of chicken-rearing in 1970, and the resulting curtailment of an incidental food supply for the pheasants. The largest counts around West Light and the Meteorological Station were 16 on 8 November 1968 and 18 on 28 December 1969. Two hens in the fall of 1970 were the last birds seen alive, but remains of at least 40 on the whole island were found by DW et al. in April 1971, and this probably indicates their final abundance. Nests were found with 12, 8, and 17 eggs (the last with 8 remaining unhatched, and probably produced by 2 females). Young broods were seen frequently in mid- to late June, and flying young as early as 29 June 1968.

Limpkin *Aramus guarauna*

One was well-observed by CB and NB on 12 September 1964 and another was seen by them briefly on 27 November 1967. The first bird was observed for about 0.5 h and at close range for 5 min. Its brown, white-streaked neck, back, and breast, long bill and neck, and long legs, were all clearly observed. The second bird, similarly brown and white-streaked, flew by at close range, but did not settle within sight. Its extended neck and legs and odd wingbeat (described by CB as resembling that of the European White Stork, *Ciconia ciconia*, with which she was familiar) were noted. These sight records, together with that of an injured bird captured in the mid-1950's on Brier Island, Digby Co. (W. Lent, in verb.) appear to be the only records north of Maryland on the Atlantic Coast.

Virginia Rail *Rallus limicola*

Spring individuals occurred on 7 June 1966 and during 6-23 May 1969, the latter at times feeding on sowbugs (Isopoda) around a house (CB). There were 6 individuals in fall of 4 years, between 24 August and 16 September.

Sora *Porzana carolina (AMNH)*

One on 29 June 1965 was around buildings near West Light. Others were flushed as frequently from dunes as from pond margins, almost all in autumn (Table III). Nine of these were counted around ponds near West Light on 16 September 1973. The Bouteilliers reported a Sora and an unidentified rail in fall, as additions to the fragments in the Dwight collection labelled 10 September 1898.

Yellow Rail *Coturnicops noveboracensis*

A small, buffy rail with white on the wing was flushed by DW on 16 September 1973. Characteristically, it could not be put up again for other observers.

Purple Gallinule *Porphyrula martinica*

There have been 4 records, all of adult individuals: on 7 July 1965 (CB, NB), 11 August 1967 (CB, NB), 11 June 1971, far from water (WS and John Shaw), and 21 July 1978 (IM).

Common Gallinule *Gallinula chloropus* (P; AMNH)

Individuals occurred on 11 September 1964, 19 August 1966, 26 May 1968, 3-5 November 1968, 14 June 1973, 15 November 1977, and 31 August 1979. The specimen on 5 October 1896 appears to be a provincial first, and Bouteillier (1908a) reported individuals on 13 October and 22 November 1906.

American Coot *Fulica americana* (P)

The species has become regular in fall (Table III), as in the province in general. Two on 1-2 July 1969 (CB) were unseasonable. Richard Bouteillier reported (Piers MS) a bird shot "last year, in hole in ice" (i.e. in 1900).

Semipalmated Plover *Charadrius semipalmatus* (P; AMNH, ROM, SMS)

This is a summer resident, and late-spring and early-fall migrants are not easily discernable (Table III). However, Burton (1974) believed that first fall migrants in 1970-1971 arrived in mid-July and that the species peaked in numbers during 15-25 August. An early spring bird in 1972 (Table VII) was part of that season's abnormally early flight of shorebirds. It is noteworthy that the Bouteilliers recorded the bird consistently earlier than our usual arrival dates (cf. Tables III, IV). Dwight (1895) found it "breeding abundantly", and it is rated as a "very common" breeding species in the Piers MS. It has certainly decreased as a nesting species since. Total island populations were estimated as: 12 pairs in 1970, 6-7 pairs in 1971, 4 pairs in 1974, and 5 pairs in 1977 and 1979. Incomplete clutches have been found, of 3 on 21 June 1963, 2 on 8 June 1966, and 1 on 24 June 1978. Hatching or newly hatched young were seen on 2 July 1967, 16 June 1971, and 5 July 1977, and newly fledged birds were seen on 21 July 1978.

Piping Plover *Charadrius melodus* (AMNH, ROM, SMS)

The bird nested at the turn of the century, but its abundance then is difficult to assess. Richard Bouteillier (Piers MS) thought it "uncommon", but they were reported as "in numbers" on 29 May 1904 (Bouteillier 1905). Dwight (1895) stated that "they are outnumbered by the Semipalmated Plover perhaps a hundred fold, but they are moderately abundant". What is certain is that they have suffered the decline shown by the species throughout its eastern range (Cairns & McLaren 1980). Elliot (in litt. 1948 to H.F. Lewis, Chief, Dominion Wildlife Service) searched for but could not find them in early August 1948, and Erskine (1953) was uncertain about their presence. The last known nest was found by CB on 15 June 1964, hatching shortly before 10 July. Otherwise it has since become an uncommon transient (Table III), and none has been seen in spring since 1969. One extraordinary bird was closely studied by CB on 25 January 1967 (not in Table III); there are no other winter records for the province. Dwight (1895) believed that the breeding birds of the island were referable to the more western race, *C. m. circumcintus*, a view echoed from their examinations of specimens by Macoun (1899) and Saunders (1902), but not entertained by modern workers (e.g. Godfrey 1966).

Wilson's Plover *Charadrius wilsonia* (P)

An individual on 2 April 1972 (Fig 6) was part of an extraordinary early flight of shorebirds that year (Table VII). It was perhaps the first well-substantiated record for the province, earlier specimens (Tufts 1973) probably not now extant.

Killdeer *Charadrius vociferus* (P; AMNH)

Transient individuals and small groups occurred regularly (Table III). However, the bird is not a "normal" migrant on the island, for most spring birds arrived in May, long after the usual time of arrival in southern Canada. It was almost equally regular in each of the 3 autumn months—September, October and November. A resident pair from 5 May to 27 June 1968 was at times agitated, but no nest was found. Two birds next year stayed through much of May, but only 1 remained from 21 May to 13 June. One between 29 June and 5 July 1969 is considered, somewhat arbitrarily, to have been between seasons (not in Table III). Others arrived in early to mid-July in several years. One appearing first on 29 December 1968 and staying until 14 January 1969, and others on 13 January 1964, 24 January 1967, 4 February 1968, 18 February 1971, and 7 March 1977 (none in Table III) may have been attempting to escape worsening conditions on the nearby mainland, where they sometimes winter. One on 2 January 1903, listed by James Bouteillier, was also noteworthy.

American Golden Plover *Pluvialis dominica* (P)

Spring records of 7 on 14 June 1965, 2 on 28 May 1966, and 1 on 16 June 1967 were unusual for Nova Scotia, although its regularity and abundance in fall are as expected (Table III). Large counts of 300 on 3 September 1969, 200 on 10 September 1974, and 220 on 2 September 1978 occurred on days with unsettled, frontal weather.

Black-bellied Plover *Pluvialis squatarola* (P)

It was regular, but scarce, in spring, and abundant in fall (Table III), with counts frequently exceeding 100 between late August and early October (ca. 1000 on 3 September 1969, 2000 during 20-25 August 1974). Burton (1974) indicates that young birds arrived in mid-August 1970-1971, some 3 weeks after the first adults, and that young birds stayed on average 13 days, adults ca. 20 days.

Common Snipe *Capella gallinago* (P; AMNH, NMC)

Spring arrival was late in most years (Table III). At least 1 winnowing male and occasionally an apparent female were seen repeatedly in early summer 1968, and flying young that year on 14 July were certainly local (IM). Vieth (1907) noted its presence in summer 1866, and stated that "some of these birds breed there". The numbers reported by the Bouteilliers in early July (Table IV) might also suggest local residency, but Richard (Piers MS) thought it did not breed. Two during 2-10 July 1976 (not in Table III) appeared to be merely unseasonable transients. One bird appeared on 25 December 1969, and a surprising twosome was found probing in deep snow near West Light on 8 January 1970, only 1 remaining next day (not in Table III).

Greater Yellowlegs *Tringa melanoleuca* (P)

An individual in early April 1972 was among several early shorebirds that year (Table VII). In most years birds lingered in June (Table III), and these along with birds arriving routinely in very early July may have been summering in the region. It was similarly early at the turn of the century (Table IV). Although Rosebrugh (1932), who lived there in 1916, included "yellowlegs" among the birds that used the island as a "summer breeding ground", this reference is casual and unsupported. Richard Bouteillier (Piers MS) stated that it "does not breed". The species is common around all ponds in fall migration. Burton (1974) believed that it was most abundant in early September with the arrival of young birds.

Lesser Yellowlegs *Tringa flavipes* (P)

It was occasional in spring (Table III), but one in 1972 was most unusual (Table VII). James Bouteillier listed 2 on 5 July 1902, earlier than any recent ones. Large groups of 50-90 birds occurred several times between early August and early October. Burton (1974) concluded that in 1970 peak numbers of adults occurred in the second half of August, and of immatures in the first half of September.

Solitary Sandpiper *Tringa solitaria* (AMNH, NMC)

The bird was more regular in spring than it is on the mainland (Table III), and the bird on 28 April 1978 (AR) is the earliest (although probably "normal") for the province, apart from one listed for 25 March 1903 by James Bouteillier. This record is interesting, in view of the migratory seasons of smaller species of Old-World *Tringa*. It was regular in fall (Table III), but counts of 6 on 27 August 1969 and 9 on 27 August 1970 were exceptional. The bird on 16 November 1969 (CB) is the latest on record for the province.

Willet *Catoptrophorus semipalmatus* (P; AMNH)

Spring arrivals were late by mainland standards (Table III), except for an abnormally early one in 1972 (Table VII). The only substantial count was of 13 on 8 May 1967. A few appeared and lingered in June, but no breeding behavior was evident. It is noteworthy that 21 of 31 fall birds seen since 1966 have appeared after 31 August. Two on 21 December 1972 (P. Dunning) were unprecedented in the province (not in Table III). One on 30 August 1969 was identified by sight by DWF as one of the large, pale *C. s. inornatus*. This western race has subsequently been seen elsewhere and collected in the province, and it may be that most late Willets are western, as they are in New England. The bird on 2 April 1972 (Fig 7) appeared to be of this race, vagrant at this season. As expected, the specimen in the Dwight collection taken on 16 May 1902 is *C. s. semipalmatus*. Two on 21 May 1902 were "the first ever noted", and it was not listed subsequently. Bent (1927) has it as breeding on Sable Island, but this probably represents confusion with Cape Sable Island, Shelburne Co.

Spotted Sandpiper *Actitis macularia* (P; AMNH)

The species nests, but either arrived late or was overlooked most springs until late May or June (Table III). The Bouteilliers gave somewhat earlier arrival dates (Table IV). Total island counts in recent years during June were ca. 12 pairs in 1970, 15-16 in 1971, 6 in 1974, 5 in 1977, 4 in 1978, and 6 in 1979; it cannot be rated as common now. Dwight (1895) listed it as the least common of the island's breeding birds, whereas Richard Bouteillier (Piers MS) thought it "rather common" and Saunders (1902) "quite common". The nesting season can be delimited by the following: an incomplete clutch of 3 on 21 June 1965, a brood hatching on 8 July 1968, and recently hatched chicks on 13 July 1975 and 6 July 1976. Probable migrants were banded as early as 3 August 1970 by Burton (1974), and maximum fall counts seldom exceeded 10 birds.

Ruddy Turnstone *Arenaria interpres* (P; SMS)

It was scarce in spring (Table III), but there were counts of 50 or more as early as in the latter half of August, in agreement with the peak noted by Burton (1974) in 1970. Individuals were observed (IM et al.) eating putrid flesh of beached Pilot Whales in early September 1973. Two on 21 January 1979 (AR) are among the few winter records for the province.

Red Knot *Calidris canutus* (P; AMNH)

Spring records are unusual for the province (Table III), and a bird in early April (Fig 7; Table VII) was more so. It was not common in fall (Table III). with a maximum count of 25 on 20 August 1977. A flock of ca. 100 on 30 January 1978 was carefully studied by WS; there are a few winter records for the province, but never in such numbers.

Purple Sandpiper *Calidris maritima* (AMNH)
Although the island does not offer its usual habitat, up to 6 migrants were seen near West Light between 7 September and 1 October 1976 (AL, AR), and 6 winter birds were on the beach on 23 February 1971 (DW). The specimen in the Dwight collection is dated 26 February 1903.

Pectoral Sandpiper *Calidris melanotos* (P; AMNH)
The spring records are unusual (Table III), and the very early bird was unprecedented (Table VII). It was regular in autumn (Table III), with large counts of 60 on 29 September 1970 and 30 on 17 October 1975. The Bouteilliers found it regularly (Table IV).

White-rumped Sandpiper *Calidris fuscicollis* (P; AMNH)
This species was occasional in spring and abundant in fall migration (Table III). Two on 11 July 1965 were early fall migrants. Burton (1974) found that adults arrived before young birds, and peaked in late August to mid-September. Counts of 100-500 were made during 5 years of 1967-1979, between 20 August and 13 September. The Bouteilliers also listed it often (Table IV).

Baird's Sandpiper *Calidris bairdii* (P)
The bird is a scarce fall migrant, as in the province in general (Table III). There are no records from earlier times.

Least Sandpiper *Calidris minutilla* (P; AMNH, ROM, SMS)
The species nests here and there on the Nova Scotia mainland, and commonly on the island (Fig 8). An exceptionally early bird (Table VII) and 1 on 25 April 1971 (Table III) are respectively earliest and second earliest spring records for the province. Burton (1974) believed that first fall migrants of non-island adults arrived in mid-July 1970, and immatures mostly 2 weeks later. Up to 200 were present in early September 1969, and 125 on 23 August 1978. Nesting was noted by Gilpin and described concretely by Dwight (1895). Recent population estimates on the whole island in June were 103 in 1970 and 167 in 1971, the latter based on thorough surveys. An effort was made to find and monitor nests in 1970. Clutches were complete on 28 May, 30 May, 4 June (3 nests), and 5 June. Incubation times (first laid to last hatching) were 19, 20 (3 nests), and 21 days. Eight of the 10 nests produced young. Much more extensive studies were made by Miller (1977, 1978, 1979) in 1975-1976, as outlined under Recent Research on Birds.

Curlew Sandpiper *Calidris ferruginea*
Five individual birds have offered ample opportunity for study: on 26 January 1968 (CB), on 26 July and 10 August 1968 (believed different birds by CB), on 22 November 1970 (DW), and on 24 August 1978 (G. Yaki, IM et al.). There has been an equal number of sightings of this Old World species elsewhere in the province.

Dunlin *Calidris alpina*
The bird has been rare in spring (with 1 on 8 May 1964 in addition to that in Table III) and surprisingly uncommon in fall.

Semipalmated Sandpiper *Calidris pusilla* (P; AMNH)
The bird is occasional in spring and abundant in fall migration (Table III), birds in late June and early July possibly representing nonbreeders. The bird on 3 May 1976 is an early record for the province. Estimates of 200-1000 birds were made

during 7 years of 1967-1979, between 20 August and 2 October. Burton (1974) concluded that adults were most common during the first half of August and immatures in the first half of September 1970-1971.

Western Sandpiper *Calidris mauri* (P; UM)
A specimen collected by JBu on 9 September 1970 (Ouellet et al. 1973) was the first authenticated record from Nova Scotia. At least some of a large group (80+) of small "peep" on the flooded south beach on 23 December 1963 were thought by CB and NB to be this species (long, drooping bills and rusty scapulars on some). A well-marked bird was seen on 15 September 1973 (Fig 9). A specimen labelled *mauri* in the Dwight collection has been propertly relabelled *pusillus* by a subsequent examiner.

Sanderling *Calidris alba* (P; UM)
The species is an abundant migrant (Table III) and regular winter resident. Winter counts made during extensive travel on beaches in January-February of 6 years ranged between 25 and 40. There were no records between late February and late March, so spring arrivals (Table III) were detectable; Bouteillier (1905) reported "a flock" on 4 March 1904. They were most abundant in autumn with an estimated 1100 on the entire island on 15 October 1971.

Stilt Sandpiper *Micropalama himantopus* (P; AMNH)
The spring record (Table III) is unusual, but it is more regular, although rare, in fall. A bird on 30 June 1966 was somewhat early. The specimen described by Dwight (1903) as a first provincial record was taken on 18 August 1902.

Ruff *Philomachus pugnax* (P)
A female was closely observed on 15 August 1965 (CB, NB); a drab male was photographed on 29-30 May 1975 (DWF); and at least 4 occurred in summer 1978 (IM, HR et al.): an adult male and a female during 19-25 July, a female on 23 August, and a young male on 1-2 September.

Upland Sandpiper *Bartramia longicauda* (P; AMNH)
This species, which has not yet nested in the province, was evidently first collected (no date given) in Nova Scotia on Sable Island (Gilpin 1882). A bird taken on 1 May 1902 (reported on James Bouteillier's list, dated 2 days earlier) is in the Dwight collection, and others were observed by Bouteillier (1906) and by Erskine (1953), who expressed reservations. In recent years, individuals have occurred on 31 May 1965 and 5 June 1966, and regularly since 1966 (Table III), often lingering on the island for days in spring. The bird on 26 April 1969 (which stayed until 7 May) is the earliest on record from the province.

Buff-breasted Sandpiper *Tryngites subruficollis*
Records by the Bouteilliers (1901; 1906) on 2 September 1901 ("numerous") and 12 September 1905 (1 bird) are the first records for the province, apart from vague references in Gilpin (1882). It is rare in fall, but probably more regular than Table III suggests. The bird closely observed in the dunes on 20 May 1978 (IM) was the second spring record from the province.

Whimbrel *Numenius phaeopus* (P; AMNH, SMS)
The spring records on Table III, as well as 2 on 11 May 1966 and 1 on 10 June 1907 (Bouteillier 1908b), are unusual for Nova Scotia, and an early bird in 1972 (Table VII) was quite abnormal. In August and early September, groups of 25 or more have been seen resting at bases of dunes along the south beach. In addition to the 3 autumn specimens in the Dwight collection, there is a bird of the Old-World race, *N. p. islandicus*, taken at sea 100 km south of the island on 23 May 1906 (Brewster 1909).

Fig 7 A Willet and a Red Knot were among the abnormally early shorebirds on the island in 1972. The pale, long-billed, long-legged appearance of the Willet strongly suggest that it was a vagrant individual of the prairie race. (Photo: 2 April 1972, D. Welsh.)

Fig 8 A Least Sandpiper nesting near West Light. (Photo: early June 1968, I. McLaren.)

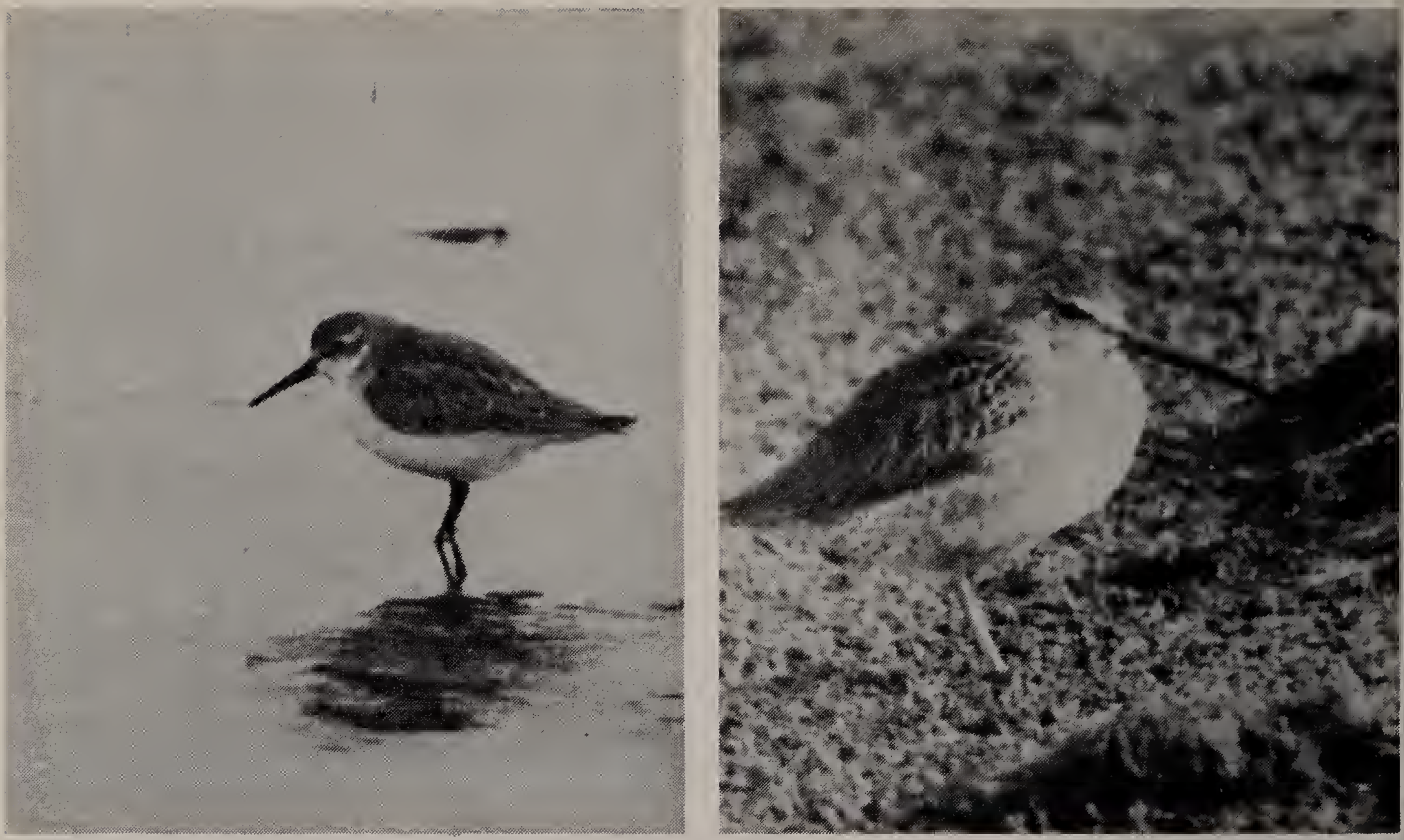

Fig 9 Well-marked individuals of the Western Sandpiper (left) and Long-billed Dowitcher (right) were found near Old No. 3 Station. Earlier specimen records of these 2 species were the first from Nova Scotia. (Photos: left, 15 September 1973, D. Welsh; right, 13 September 1973, I. McLaren.)

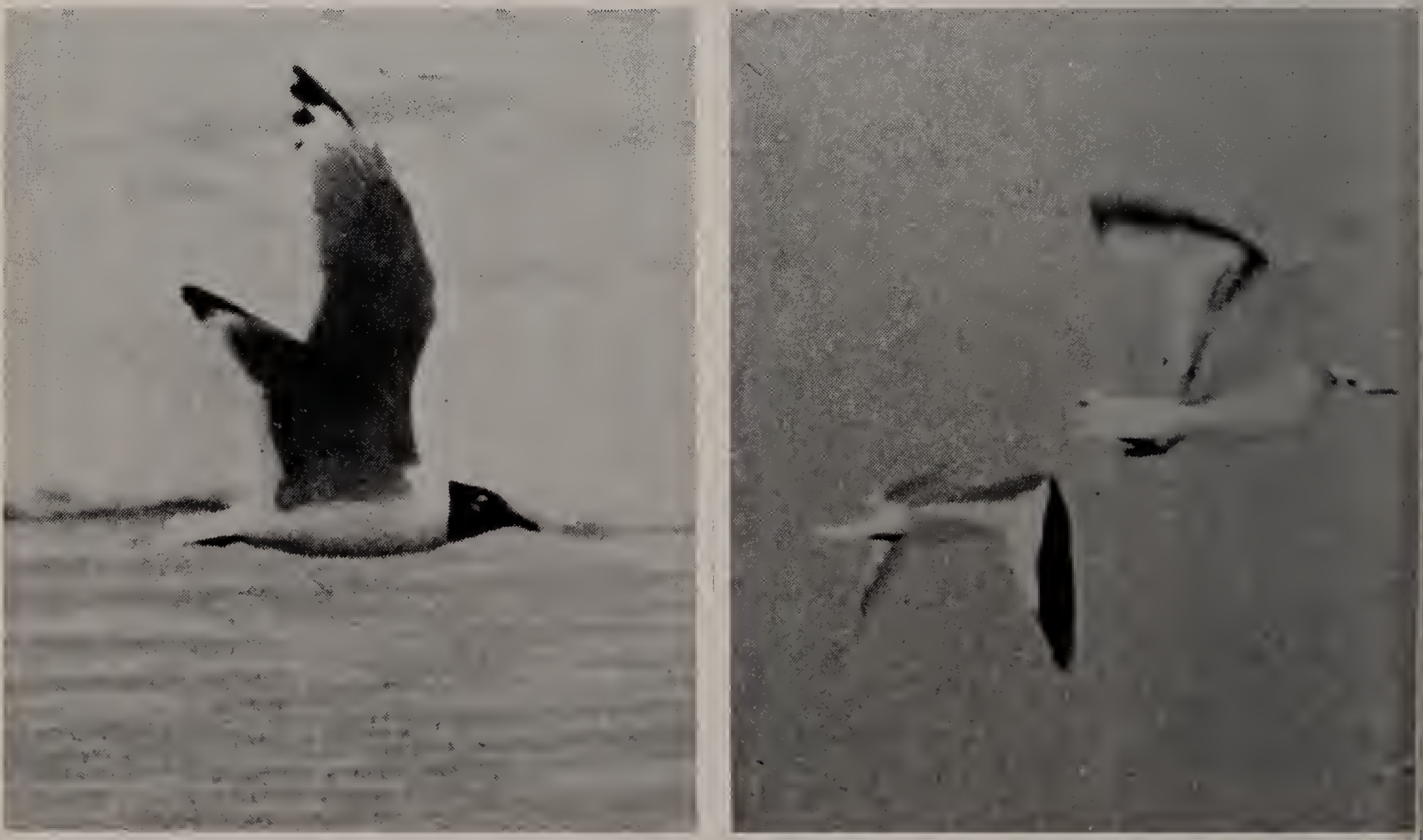

Fig 10 The Franklin's Gull (left), far from its prairie nesting range, was a first provincial record. The Sabine's Gull (right), conspicuous among Kittiwakes at the island's west tip, was a first authenticated record. (Photos: left, 26 May 1973, J. Boulva; right, 12 June 1977, I. McLaren.)

Eskimo Curlew *Numenius borealis* (AMNH)

What seems to be the last Nova Scotian record is a specimen (a head only) labelled "? fall of 1902" in the Dwight collection. The query may mean that the fragmentary specimen was found as such and attributed to a fall arrival. The specimen is referred to by Swenk (1915).

Marbled Godwit *Limosa fedoa* (P)

One was feeding among other shorebirds on the south beach on 12-13 September 1972 (IM et al.), and another was carefully studied on the extraordinary date of 8 June 1979 (B. Mactavish; Z. Lucas).

Hudsonian Godwit *Limosa haemastica* (P)

The bird probably occurs more regularly in fall than Table III suggests. In addition, a bird on 6 June 1965 (black wing linings noted by CB, NB) was evidently the first spring record for the province (an unidentified godwit was seen by AR on 11 April 1975).

Short-billed Dowitcher *Limnodromus griseus* (P)

Dowitchers are regular in spring and abundant in fall (Table III). A bird in 1972 was clearly abnormally early (Table VII), and otherwise the bird on 3 May 1976 (Table III) is an early record for the province. The bird on 29 June 1971, 2 weeks later than any other June bird, was assumed to be an early fall migrant (Table III). Burton (1974) found that adults appeared on 13 July 1971 and peaked later in the month, whereas immatures appeared in late July, and did not peak until late August and early September.

Long-billed Dowitcher *Limnodromus scolopaceus* (P; AMNH)

The specimen in the Dwight collection was a first provincial record (Pitelka 1950). The date on the label is 4 October 1897, not 31 October as given by Pitelka and others since. In addition, several have been carefully identified in recent years: 2 on 2 October 1970 (DW), up to 5 on 13-15 September 1973 (e.g. Fig 9), 2 on 12 September 1974 (B. Mactavish), 1 on 13 September 1977 (IM), 3 on 26 August (Arnet Sheppard) and 1 on 10 September 1978 (IM et al.).

American Woodcock *Philohela minor* (P)

A few Woodcock have occurred beginning in 1970 (Table III). Numerous probe marks in the wormless sand on 4 April 1972 bespoke some frustration.

American Avocet *Recurvirostra americana*

A single bird on 17 September 1969 (CB, NB) followed by about 3 weeks the first record for the province, on the mainland.

Red Phalarope *Phalaropus fulicarius* (P; AMNH, NSMS, ROM)

Although it is probably regular around the island, it has been seen in spring 1967-1979 only between 18 May and 5 June, usually in ones and twos. However, on 29 May 1977, flocks of 50-300 passed in numbers over the island in a southeasterly direction; an estimated 16,000 birds passed within visible range that morning. The Bouteilliers recorded it regularly (Table IV) in large numbers ("doz. of flocks of abt. 50 to 100 each") on 21 May 1906. It was also reported on 3 July 1902, and the 11 specimens in the Dwight collection include 7 taken on 13 July 1894. The only recent fall migrants were 3 on ponds during 26 August to 15 September 1977.

Wilson's Phalarope *Steganopus tricolor* (P)

The sight record of a bird on 7 June 1905 (Bouteillier 1906) is evidently the first for the province. Two were seen on 31 October 1966, and it has been sufficiently common since to be entered in Table III.

Northern Phalarope *Lobipes lobatus* (P; AMNH, UM)

Since 1966 there have been only 3 individuals during 3 springs (23 May - 14 June) and about 20 fall migrants during 4 years (20 August - 27 September). Bouteillier (1908b) reported an earlier spring bird on 13 May 1907 and there is a late specimen in the Dwight collection from 4 October 1902.

Pomarine Jaeger *Stercorarius pomarinus*

Although Brown et al. (1975) indicate that this is the commonest jaeger in waters near the island, only 8 individuals have been identified on the island: 5 during 4 springs of 1967-1979, between 7 May and 2 June; 2 on 14-16 September 1977, and 1 on 3 September 1979. James Bouteillier listed "jaeger gulls" on 30 May 1902, and Richard (Piers MS) thought them "common out at sea".

Parasitic Jaeger *Stercorarius parasiticus* (P; AMNH)

The great majority of identified jaegers have been of this species. The earliest in spring was on 10 May 1971, and the latest were 3 on 16 September 1977. Totals by month since 1967, including some unidentified jaegers best attributed to this species, were: 43 in May, 62 in June, 6 in July, 9 in August, and 21 in September.

Long-tailed Jaeger *Stercorarius longicaudus* (AMNH, SMS, Austr. Mus.)

Two adults were seen on the beach and in flight on 9 June 1968 (IM); a bird flew close overhead on 13 June 1977 (HR, S. McCormack), and 2 adults were seen along the beach on 4 June 1979 (B. Mactavish). The 6 immature birds in the Dwight collection were all taken on 15 August 1896 and are evidently the first of the species from Nova Scotia.

Great Skua *Catharacta skua* (P)

Skuas are regular around the island (Brown et al. 1975), and are occasionally seen from shore. Since 1970, 3 individuals have been seen in March, 9 in early June, 1 in early July, and 1 in mid-August. Only 6 of these birds have been identified with some assurance as Great Skuas, and recent occurrences of *C. maccormicki* should be kept in mind. Richard Bouteillier (Piers MS) thought that Skuas were "common about the island", and they were listed as "skua gulls" for 7 June 1906 (misleadingly as "Gulls" in the published version) and as "squa gulls" for 18 July 1907.

Glaucous Gull *Larus hyperboreus* (P; AMNH)

Only some 27 individuals have been reported during 1967-1979. The earliest was in mid-September 1979 (WS), and the latest was on 31 May 1976 (IM). One of the 2 specimens in the Dwight collection is labelled "caught in trap . . . 25 February 1895", probably set for the infamous foxes of that time.

Iceland Gull *Larus glaucoides* (P; AMNH, ROM)

Much more regular and abundant than the Glaucous Gull, this species was reported as early in fall as 23 September 1963. Up to 250 were found on the whole island in mid-February 1970, and again in late January and early April 1972. Sightings of 1-3 birds were made routinely into June; the median date of last sightings during 1967-1979 was 5 June, and the latest was on 24 June 1977. An injured year-old bird was found on 27 August 1974. The subspecies *kumlieni* certainly can be found commonly (3 specimens), and *glaucoides* (1 labelled as *leucopterus* by Dwight) is probably less frequent. During early April 1972, the less common white-primaried adults, which appeared rather more delicate in form, occurred mainly along the beaches, often with seal herds, whereas readily identified *kumlieni* were concentrated with other gulls at the island's tips (IM).

Great Black-backed Gull *Larus marinus* (P; AMNH,NMC, NSMS)

An estimated 630 pairs nested on the island in 1970 (Lock 1973). Some whole-island estimates for other seasons were 1150-3500 individuals during September of 6 years, 2000 on 20 February 1971, and 400 on 19 January 1972. Few immature birds stay in winter. Early reports by island superintendents (Nova Scotia Archives) of exploitation of "gull eggs", when explicit, refer to "mackerel gulls" or "small gulls"—that is, to terns. There is no evidence that *Larus* gulls nested in the 19th century. At the turn of the century, they were thought (by Richard Bouteillier, in Piers MS) to be the more numerous of the 2 large gulls, but even then they did not nest (Dwight 1895; Saunders 1902a). They were probably present more commonly in winter, for James Bouteillier noted on 3 May 1902 that "about all the Great Black-backed Gulls, Grey Gulls [immatures?], and Herring Gulls are gone", but that "200 or more stay on the east and west bars during the summer". Rosebrugh (1932) states that gulls were breeding in 1916, but his list of breeding birds may be overly casual (e.g., see under Greater Yellowlegs). Lock (1973) thought that they began to breed around 1920. He studied their breeding biology intensively in 1969 and 1970. First nests occurred on 29 April 1969 and 1 May 1970, and peak of laying was during 10-15 May in both years. He concluded (see Recent Research on Birds) that they are quite successful on the island. Adults have been seen recently killing Harbor Seal pups. However, the situation is reversed during the winter breeding season of the island's Gray Seals, adult females of which have been seen killing or maiming numbers of black-backs in apparent defense of their pups (B. Beck, in verb.). In spring 1977 a die-off of perhaps hundreds of black-backs was attributed by residents to food poisoning from decaying flesh of large numbers of Pilot Whales, stranded in December 1976.

Lesser Black-backed Gull *Larus fuscus*

An adult paused briefly near West Light on 5 September 1979, then flew westward off the island (ELM).

Herring Gull *Larus argentatus* (P; AMNH, NMC, NSMS)

An estimated 2000 pairs nested on the island in 1970 (Lock 1973). Some other estimates for the whole island were: 550-1000 during early to mid-September of 4 years, 300 on 24 October 1973, 400 in mid-November 1977, 500 in mid-January 1972, 200 in late February 1971, and 700 in early April 1972. Immatures are rare in winter, and in early spring 1972 were not seen during extensive travels until 10 April. As noted under the previous species, *Larus* gulls may not have nested until about 1920. Lock (1973; see also Recent Research on Birds) found seasonally first eggs on 8 May 1969 and 5 May 1970, with peaks of laying about 24 May and during 20-25 May during the 2 years. There was a peak of re-laying on 21 June 1970.

Ring-billed Gull *Larus delawarensis* (NMC)

Two on 12 December 1963 and 2 on 17 November 1965 have been followed by sightings of only 20 during 1967-1979. Nine appeared in spring between 11 April and 12 June (1 unusually early on 8 March 1969), and 10 between 24 July and 28 December (an additional oiled bird stayed from 8 November 1968 to 31 January 1969). Richard Bouteillier gives the only older record, a bird on 3 November 1908. A recently fledged female, first seen on 13 August 1972 and found dead on 22 August, had quite heavily sheathed remiges and retrices and "was probably not sufficiently well developed . . . to travel very far" (W.E. Godfrey, in litt.), which poses a minor mystery.

Mew Gull *Larus canus*

On 9 March 1969, an adult was closely observed as it perched and flew around West Light (CB, NB), for a first provincial sighting. The Old-World *L. c. canus* would seem more probable at this season.

Black-headed Gull *Larus ridibundus* (P)

Only 4 individuals have been noted: on 13 February 1970, 28 May 1974, 12-15 November 1977, and 30 May 1978. The May birds were somewhat late for the province.

Laughing Gull *Larus atricilla* (P)

Large numbers appeared after a hurricane on 24 October 1968. There were still 100+ on 4 November, some dying, and a few until 12 November. Otherwise the bird has been regular in small numbers with records from 1967-1979 by month as follows: 6 in May, 10 in June, 3 in July, 4 in August, 1 in September, 4 in October, and 12 in November. A bird on 27 January 1972 (JB, DW) was among the few winter records from the province.

Franklin's Gull *Larus pipixcan* (P)

An adult was seen regularly between 26 May and 2 June 1973 by JB (Fig 10), and a year-old bird was present between 23 August and 13 September 1978 (IM, G. Yaki et al.; photos). There are no other Nova Scotian records of this prairie gull.

Bonaparte's Gull *Larus philadelphia* (AMNH)

The bird is irregular and rare, with individuals in recent years on 25 November 1969, 19 November 1970, 17 February 1971 (immature, well studied, DW), and 12 September 1972, and 2 birds on 23 August 1973. Erskine (1953) reported 1 in late August 1953. The fragmentary specimen in the Dwight collection is labelled "winter of 1898-99".

Little Gull *Larus minutus* (P)

Two Little Gulls in first summer plumage spent time near West Light on 10 June 1975 (DWF). Another in juvenile plumage was seen briefly on 27 August 1978 (P. & R. Gilchrist). Both the June and August birds were chased by terns.

Ivory Gull *Pagophila eburnea*

An astonishing record is of an adult that spent the day near West Light on 20 June 1969 (CB, NB). Other more seasonable sightings were of single adults on 25-29 April 1976 (AR, J. & S. Redmond) and on 1 February 1979 (D. Gray). A specimen was taken near Sable Island on 9 December 1905 (Allen 1916).

Black-legged Kittiwake *Rissa tridactyla* (P; AMNH, NSMS, ROM)

There are recent records for every month, but it has been most abundant in May and November. Most summer birds are immature, as are 7 of 8 specimens in the Dwight collection. The bird is most commonly seen at the island's tips, sometimes on the beaches. It was present in unprecedented numbers during May and early June 1978, feeding voraciously along the island's beaches on swarms of the amphipod *Parathemisto gaudichaudi*. The Bouteilliers seldom listed it, perhaps because it was commonplace and "very numerous" (Piers MS).

Sabine's Gull *Xema sabini* (P)

Two adults flying over the south beach on 15 February 1965 (CB) and another on 19 December 1966 (CB, NB) were extraordinary. They were sufficiently close so that forked tails, in addition to the diagnostic wing patterns, could be appreciated. There have been subsequent winter sightings near the southern end of the province. Other birds on Sable Island have occurred at more usual seasons: in fall, an immature on 27 August 1969, another on 12 September 1974, and an adult and immature on 16-29 October 1978; and in spring, with Kittiwakes at the west tip, adults on 12 June 1977 (Fig 10), 26 May 1978, and 19 June 1979.

Gull-billed Tern *Gelochelidon nilotica*

Tufts (1973) erroneously reported that R. Bouteillier made a first Nova Scotian sighting of this species on 10 June 1902. This is the date of Bouteillier's interview with Piers, who wrote (Piers MS) on the tern: "Rare. Sometimes rather plentiful. Thinks it breeds. Summer." This tantalizing statement deserves serious consideration, since the Bouteilliers certainly reported and collected the 3 usual breeding terns. The bird has been seen a few times in recent years elsewhere in Nova Scotia, usually in midsummer.

Common Tern *Sterna hirundo* (P; AMNH, ROM, SMS)

On 15-16 July 1971, A.R. Lock (in verb.) counted 2585 terns around colonies, fishing in the sea, and resting on beaches. About 60% were Arctic, 30% Common, and 10% Roseate Terns. In late May 1977, I estimated more roughly that there were 5000 terns, but many could have been transient. Terns arrived on the island with marked regularity during 1967-1979 (earliest 7 May, latest 17 May, median 10 May). Their departure was less regular. Many adults left the island colonies in early August; the median date of last sightings was 26 September and the latest was a Common Tern on 28 October 1979 (AR). The terns nest in pure and mixed colonies. Nests have not been looked for in all years, as colonies were generally avoided. First nests were found on 18 May 1977, 20 May 1978, and 20 May 1979 (species uncertain), but it is believed that most birds do not lay before June. The latest incubated clutch was of a Common Tern on 14 August 1970. Fledglings appeared after mid-July. A nearly fledged Common Tern was found as late as 13 September 1974.

Terns were clearly much more abundant in earlier times. Dwight (1895) thought that two-thirds were Arctic, the rest Common, with "a sprinkling" of Roseate Terns. Saunders (1902a) thought that the "common tern probably outnumbers the arctic by two or three to one". Dwight was probably more familiar with terns and spent more time on the island. References to numbers are generally casual. Saunders (1902a) refers to "many tens of thousands". Superintendent R.J. Bouteillier's diary (Nova Scotia Archives) accounts for a minimal 30 1/2 buckets of terns' eggs collected in 1886. William Saunders (father of W.E.), who was in charge of the massive tree-planting operations of 1901, was interested in the fertilizing role of the terns. He writes (quoted in St. John 1921) "after travelling over the greater part of the island and seeing the immense numbers of terns everywhere, from a rough computation per acre and the acreage of the island, we estimated that these birds alone did not fall far short of a million on the island." Another interesting difference between the terns in those times and today is their earlier arrival in the past. The arrival of terns during 11 years between 1845 and 1908 (superintendents' diaries, plus the Bouteilliers' records in Table IV) was as early as 23 April and as late as 5 May, with a median of 28 April, almost 2 weeks earlier than in recent years (see above). The difference could be due to change in mean or variance in the arrival time, or to the much greater probability of sighting the vanguard of the massive population in earlier times. The tendency for earlier arrivals in the 19th century was evidently not expressed in earlier nestings. First nests (or eggs) were reported during 6 years between 1850 and 1901 as early as 20 May and as late as 28 May, with a median of 25 May, no earlier than in recent years. The Bouteilliers also reported them as late as 25 October in 1902 and 1908.

Arctic Tern *Sterna paradisaea* (P; AMNH, NMC, SMS)

Arctic Terns nest in numbers today, but were immensely more common in the last century (see under previous species). They arrived with regularity in early May, sometimes a day or so later than first-sighted Common Terns. Their breeding schedule seems to be about the same as that of the Common Tern, except that they finish earlier. A few rather recently fledged young were noted on 10 September 1974, but generally all were gone before mid-September. The latest, a group of largely immature birds on 1 October 1976, may have been transient. Varying numbers of subadult Arctic Terns occurred on the island from year to year. Of 28 skins in the Dwight collection, 12 are in the *"portlandica"* plumage. In 1973 it was estimated in late May and early June that almost one-third of this species in groups resting on beaches were in this plumage. In 1977, on the other hand, fewer than 1% of such groups were subadult. The subadult birds were involved in defence around colonies, but were not seen at nests.

Roseate Tern *Sterna dougallii* (P; AMNH, ROM, SMS)

This (Fig 11) is the least abundant nesting tern, with some 250 on the island in mid-July 1971 (see under Common Tern). This may be a somewhat high estimate, but it did nest successfully in numbers. Of 93 near-fledging terns banded in colonies near East Light between 28 July and 3 August 1970, 46 were Roseate and the rest Common. In recent years, however, Roseate Terns have declined sharply in abundance. No more than 5 pairs were seen on the west half of the island in 1978 and 1979, and possibly 10 pairs occurred in the east half in 1979. What was the largest concentration of breeding Roseate Terns in Canada now seems to be disappearing. Similar declines elsewhere are attributed to exploitation by humans of the tern's winter range (Nisbet 1980). The birds arrived later and departed sooner than did the other breeding terns. The earliest was on 13 May, and the median 17 May, during 1967-1979. These dates hardly differ from those in Table IV. The latest in fall were 12 birds on 27 September 1970.

Sooty Tern *Sterna fuscata*

An immature bird was observed with Arctic Terns, dip-feeding close to the south beach on 4 July 1972 (DW). No storm had occurred within days prior to the occurrence. There are a few other records from the province.

Least Tern *Sterna albifrons*

Richard Bouteillier's comments on this species are summarized (Piers MS) as: "only about 20 or 30 specimens in ten years. Fall. Does not breed." James Bouteillier listed "several" for 11 September 1908. Both accounts are plausible, since they obviously knew the regular terns, and since the Least Tern has occurred occasionally elsewhere in the province.

Royal Tern *Sterna maxima*

Five of this southern tern were seen fighting 50-knot, post-hurricane gales on 16 August 1971 (DW). They were exhausted and permitted close inspection in flight and on the beach. There are 2 specimens and 3 sight records from elsewhere in the province.

Caspian Tern *Sterna caspia.*

The 3 sight records are of 1 on 17 July 1963, another unseasonable on 29 June 1967 (both CB, NB), and of 2 on 4 November 1968 (IM et al.). The species is a rare transient in the province.

Black Tern *Chlidonias niger* (P; AMNH, SMS)

Records since 1967 (Table III, the bird here reckoned as a freshwater species) imply a surprising regularity offshore for a bird that has just begun to breed in the border region of the province. Early July adults in 3 years may have been nonbreeders. Generally they appeared in ones and twos, often staying around the island's ponds for days, but some were seen at the island's tips. The 2 specimens were taken on 31 August 1900 and 9 September 1902, only the latter reported by Dwight (1903).

Black Skimmer *Rynchops niger* (P)
One was seen on 14 August 1965, "furrowing" a shallow pond near the Meteorological Station (CB, NB). Remains of another in May 1969 were doubtless a victim of the previous October hurricane, which brought many of the species to Nova Scotia.

Razorbill *Alca torda* (P; AMNH)
In addition to the 2 males in the Dwight collection taken on 28 November 1900, a bird was seen alive on shore on 5 February 1964, remains of 3 have been found on beaches (1 in "Arrow" oil; Brown et al. 1973), and individuals have been sighted from boats near the island on 18 May 1976 and 15 May 1977. It is probably more regular around the island than these few records suggest (Brown et al. 1975). The statement on the terse list by Downs (1888) that it "breeds on Sable Island" is unsupported and unlikely.

Common Murre *Uria aalge* (P)
Large numbers were seen on 12 February 1964 off the south beach with Thick-billed Murres. Small numbers have been seen off beaches at other times, and a few have been found dead or moribund of natural causes or oiling. About 125 came ashore in "Arrow" oil in late winter 1970, their home colonies probably in Newfoundland or the Gulf of St. Lawrence (Brown et al. 1973). A large number of oiled birds also appeared in spring 1977 (AR). The earliest bird in fall was on 19 October 1963, and the latest in spring were 2 on 16 May 1976. A bird on the beach during 20-25 June 1974 was injured.

Thick-billed Murre *Uria lomvia* (P; AMNH, NMC)
The few sight records of murres offshore were usually of this species when identified, as were most dead birds on beaches. An estimated 2700 came ashore in "Arrow" oil in late winter 1970, their home colonies probably in West Greenland (Brown et al. 1973). A corpse found in March 1977 had been banded as a chick in Upernavik District, Greenland, on 20 August 1974. The earliest in fall were 6 on 11 November 1963, and the latest in spring was an actively flying and diving bird on 14 June 1979.

Dovekie *Alle alle* (P; AMNH, SMS)
These birds are rather frequent as corpses and occasionally seen alive on beaches or ponds. A particularly large Dovekie "wreck" occurred on 29 December 1965. Some 1250 came ashore in "Arrow" oil in late winter 1970 (Brown et al. 1973). The bird appeared in fall as early as 2 November 1969 and live birds were seen as late in spring as 15 May 1977. They occurred in gull diets during 1969 and 1970 nesting seasons (Lock 1973), but whether taken alive or as old carrion is uncertain.

Black Guillemot *Cepphus grylle*
About 50 came ashore in "Arrow" oil in late winter 1970, but corpses of this neritic alcid could have been brought from the mainland coast in the oil.

Common Puffin *Fratercula arctica* (P; AMNH, NMC, ROM)
Some have been seen alive, and more as corpses. A few were found in "Arrow" oil in late winter 1970. The earliest live birds in fall were 5 on 20 November 1970, and 4 adults and 6 immatures were found recently oiled on 3 July 1970.

Rock Dove *Columba livia*

In recent years a "carrier" pigeon with a message container occurred on 6-11 June 1964; banded birds occurred on 19 June 1968 and 2-3 October 1973, and unbanded ones on 5 August 1965, 22 August 1968, 3 February 1969, and 2 March 1979. The implication may be that "domestic" birds are particularly prone to wandering. Pigeons were kept on the island in the late 19th century, in an attempt to alert the mainland of disasters (summarized by Appleton 1968). There is a number of references to these recalcitrant pigeons in the diaries of Superintendent Bouteillier for 1890-1895 (Nova Scotia Archives), and the project seemed clearly unsuccessful. (It is noteworthy that a son of Andrew Downs, the well-known Halifax naturalist, served as pigeon keeper in 1890-91, but there appears to be no account by him, or secondhand, of any observations on birds).

White-winged Dove *Zenaida asiatica*

A bird on 10 August 1979 was studied at leisure at distances as close as 15 m by AR. This was a first provincial occurrence, preceding by 2 weeks another individual photographed on Seal Island, Yarmouth Co.

Mourning Dove *Zenaida macroura* (P; NMC)

These doves are increasingly frequent in fall in the province, less so in spring, and this is reflected in records from the island (Table III). Large counts were 12 on 24 October 1973, 25 on 28-30 September 1974, and up to 50 beginning in mid-October 1979, of which 27 were found dead by mid-November. An unseasonable bird appearing on 27 June 1976 died on 3 July (not in Table III). James Bouteillier (Piers MS) reported in 1901 that "about two years ago a number seen in fall", and Bouteillier (1908b) listed a bird for 26 September 1907.

Passenger Pigeon *Ectopistes migratorius*

A report by Capt. William Townsend to the Nova Scotia Government on 26 April 1848 (Nova Scotia Archives) states that "as game, there is an abundance of ducks and also of pigeons and plover in their season." I can find no other mention of the possible occurrence of Passenger Pigeons in archival or published reports, but their occurrence is quite plausible in view of their onetime abundance in the province. Much more fascinating is James Bouteillier's listing of 1 on 27 October 1903. The "Remarks" column reads, in the hand of Harry Piers: "Doubtless a dove. Not in hand." Yet the Bouteilliers evidently knew the Mourning Dove (see previous species). It is perhaps idle to add another speculation on the demise of the pigeon: that individuals had poor orientation abilities, having been so long dependent on the joint skills of massive flocks.

Yellow-billed Cuckoo *Coccyzus americanus* (P)

The bird is a fairly regular vagrant on the island (Table III). Spring sightings are rare in the province. One on 14 July 1966 was early. Bouteillier (1908b) lists 1 on 26 October 1907.

Black-billed Cuckoo *Coccyzus erythropthalmus* (P; AMNH)

Most of this species arrived late in spring, the latest arriving on 23 June 1976, dying on 3 July (Table III). Birds arriving in early July are assumed to have been normal migrants; 1 on 16 July 1976 was in juvenile plumage. The Bouteilliers' 2 sightings and 3 specimens were from August to September.

Snowy Owl *Nyctea scandiaca.* AMNH)

Early reports of Snowy Owls summering on the island and exploiting rodents and rabbits (Gilpin 1858; 1881; Vieth 1907; Nova Scotia Archives, superintendent diaries) are almost matched by the recent appearance of a very tame bird on 5-6 August 1964 (CB, NB et al.). John J. Elliot (in litt. 1948, to H.F. Lewis, Chief,

Fig 11 The beautiful Roseate Tern has all but disappeared as a nesting species on the island in recent years. (Photo: June 1968, I. McLaren.)

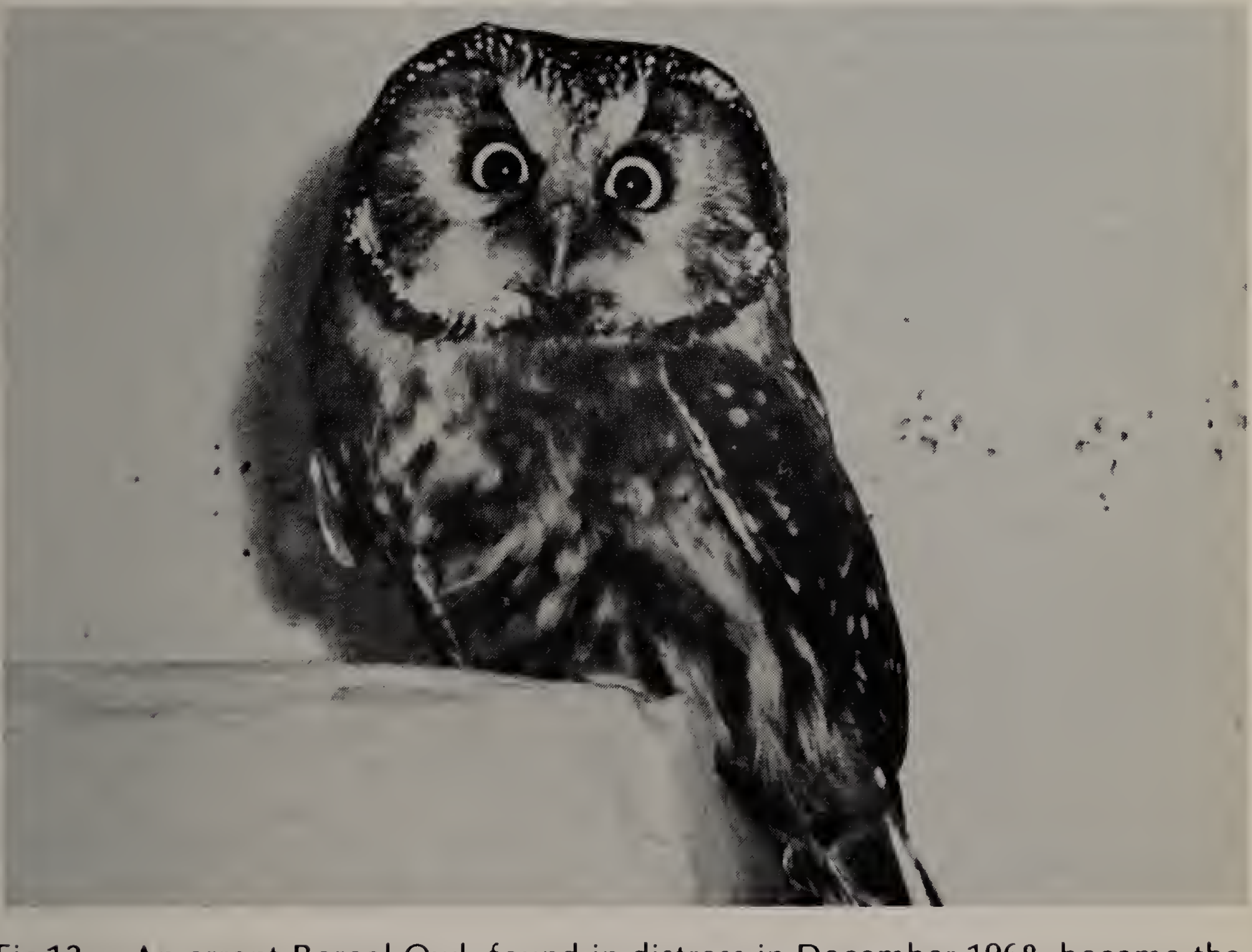

Fig 12 An errant Boreal Owl, found in distress in December 1968, became the ward of Dr. Robie Tufts, Wolfville, N.S. (Photo: 17 January 1969, I. McLaren.)

Dominion Wildlife Service) reported a bird "bent on killing rats" that had remained until late May 1948. Seven have been seen during the normal season since 1967, the earliest on 17 November 1979 and the latest on 15 March 1975. There are no rodents or rabbits now, nor pheasants, which were known to have been taken by owls (1 seen carrying a hen on 30 November 1968). The Bouteilliers' sightings and specimens were from the usual season, but a "dozen" on 25 November 1905 (Bouteillier 1906) were exceptional.

Hawk Owl *Surnia ulula* (AMNH)

Among the specimens in the Dwight collection are a female taken on 10 November 1900 and a male from the unusual date of 10 June 1902. The latter is listed by James Bouteillier as is another by Richard Bouteillier on 9 October 1908. There have been no recent reports.

Barred Owl *Strix varia*

One was found in an old barn (now destroyed) near East Light on 31 July 1966 (CB, NB), and another tame bird was seen near West Light on 10 November 1975 (AR).

Short-eared Owl *Asio flammeus*

The few sightings of individuals were : on 3 August 1964, 25 May 1966, 4 November and 22-23 November 1968, 20 May 1971, and 16-17 April 1977.

Long-eared Owl *Asio otus*

One landed on a building near West Light on 29 July 1966 and allowed close inspection (CB, NB).

Boreal Owl *Aegolius funereus* (P)

An adult Boreal Owl was picked up alive near West Light on 23 December 1968 (Fig 12). It was fed on House Sparrows until 17 January 1969, when it was sent by CB and NB to the care of Dr. Robie Tufts, Wolfville, N.S. (Tufts 1973).

Saw-whet Owl *Aegolius acadicus* (NMC)

Judging from accumulated pellets, one had been present for some days before discovery in an outbuilding near West Light on 16 August 1963, and remained for 4 more days (CB). Another struck a wire fence and was found dead on 2 December 1974 (J. Redmond). One was reported by Bouteillier (1908b) on 21 February 1907.

Whip-poor-will *Caprimulgus vociferus* (NSMS)

Birds were found recently dead on 3 June 1966 and on 31 May 1967; a live bird occurred on 19 June 1967, and another was found dying on 9 May 1970.

Common Nighthawk *Chordeiles minor* (P; AMNH)

Nighthawks were occasional (Table III), and often lingered for days, apparently feeding successfully. They arrived regularly into June, but birds in July were considered to be normal migrants, as they are on the move in the province at large then. Bouteillier (1908b) recorded a bird on 1 May 1907, earlier than any recent ones. A late specimen, taken on 7 October 1902, was listed by James Bouteillier as "the first one ever noticed here".

Chimney Swift *Chaetura pelagica* (P; NMC)

Swifts were regular in spring and occasional in fall (Table III). Bouteillier (1906) recorded a later bird, on 30 September 1905.

Ruby-throated Hummingbird *Archilochus colubris.* (AMNH)

One was seen on 3 July 1963, 2 on 11 August 1965, and a few since 1966 (Table III includes some unidentified hummingbirds, assumed to be this species). The specimen in the Dwight collection is a desiccated head labelled "summer? 1900".

Belted Kingfisher *Megaceryle alcyon* (NMC)

These birds are perhaps surprisingly common (Table III), and often linger, fishing in the island's ponds. They were also regular in the early 1900's (Table IV). James Bouteillier reported 3 unseasonable birds on 2 July 1902. Two on 28 December 1969 (not in Table III) may have been attempting to winter in the region.

Common Flicker *Colaptes auratus* (AMNH)

Flickers were regular, sometimes in small groups, especially in fall (Table III). They often stayed for days, foraging successfully on the open terrain. Two on 22 June 1963 were later than any more recent birds (Table III). One appeared unexpectedly on 20 February 1977 (AR). They were also regular in fall at the turn of the century (Table IV). All birds reported have been "Yellow-shafted Flickers".

Yellow-bellied Sapsucker *Sphyrapicus varius* (NMC)

The few records are of individuals on 21 August 1964, 17 August 1966, 5 October 1967 (dead next day), 19-23 August 1969, and of a long-dead corpse in late May 1975. Richard Bouteillier reported a later bird on 9 October 1908.

Hairy Woodpecker *Picoides villosus* (P)

Two on 3 August 1964 and 1 on 5 November 1966 were outmatched by a minor invasion in 1969, involving at least 6 birds between 21 August and 28 December. There were other birds on 21 May and 16-17 October 1975, 2 during 15-25 September 1977, and 1 on 16-24 October 1979.

Downy Woodpecker *Picoides pubescens* (P; NMC)

Recorded sparingly in most years (Table III), the Downy Woodpecker did not linger as a rule. One on 4 July 1963 was unseasonable.

Black-backed Three-toed Woodpecker *Picoides arcticus*

A male was seen on 7 August 1965 (CB, NB) and another on 15 May 1969 (E. Androschuk).

Eastern Kingbird *Tyrannus tyrannus* (P)

Kingbirds are common migrants (Table III). There were peak counts of 5-25 birds per day during 10 springs of 1967-1979, between 27 May and 12 June. Individuals often arrived and stayed in June, and several times into early July. Possible late migrants or nonbreeders were 2 on 14-16 July 1968, 1 on 12 July 1971, and 1 on 3 July 1978 (none in Table III). The Bouteilliers found it more regular in fall (Table IV) and listed an unseasonable bird on 9 July 1907.

Gray Kingbird *Tyrannus dominicensis*

One was closely observed around West Light for 3 days, 20-23 October 1973, and was well-described by AR for a second provincial sight record.

Western Kingbird *Tyrannus verticalis*

Individuals of this regular vagrant were seen on 24-25 September 1970 (JB, DW), 10 April 1971 (DW), and on 2-3 October and 17 October 1975 (AR, IM et al.). The spring bird was the first of the few from this season in the province.

Great Crested Flycatcher *Myiarchus crinitus* (P)

The bird was occasional, and rather late, in spring, and somewhat more frequent in fall (Table III). A freshly dead bird on 22 July 1963 was early.

Eastern Phoebe *Sayornis phoebe*

This was one of the less common of the regular Nova Scotian flycatchers on the island and tended to appear late in spring (Table III). Individuals on 25 June 1964 and 4 July 1971 (the latter not in Table III) were especially late or unseasonable.

Fig 13 Nova Scotia's fourth (Sable Island's only) Say's Phoebe, far from its western home. (Photo: 18 September 1974, I. McLaren.)

Say's Phoebe *Sayornis saya* (P)

A bird on 18-19 September 1974 (Fig 13) was the fourth provincial record of this western species.

Yellow-bellied Flycatcher *Empidonax flaviventris* (AMNH)

This is one of the regular and common passerines, arriving quite late and continuing to arrive in small numbers and linger through June (Table III). There were peak counts of 5-39 individuals on 7-18 June during 9 years of 1967-1979. One on 9 July 1963 was unseasonable, and a very late bird was tentatively identified as this species (CB) on 16 November 1969 (not in Table III). The Bouteilliers reported this species quite regularly in spring (Table IV), but may have been loath to identify other small species ("various kinds" on 26 September 1906; Bouteillier 1908a).

Alder Flycatcher *Empidonax alnorum*

Both *E. alnorum* and *E. minimus* have been identified by appearance and voice (the former mostly as "Traill's Flycatcher"), but most records did not discriminate (Table III). Of those that did, there were 40 Alder (or "Traill's") and 22 Least Flycatchers. The earliest Alder Flycatcher was on 18 May 1977 and the latest in spring (as "Traill's") was on 26 June 1975. An unidentified *Empidonax* on 26 April 1969 (E. Androschuk; not in Table III) was very early, but 4 birds during 1-4 May 1975 were not unprecedented in the province. The only counts exceeding 5 per day were on 10 June 1967, 7 June 1968, and 10 June 1974. One *Empidonax* sp. on 6 July 1972 was between seasons. They were less common in fall. The earliest identified as "Traill's" was on 1 August 1978, and the latest was on 15 September 1978. Nothing can be said about the possibility that some of these birds were Willow Flycatchers *(E. traillii)*, a pair of which was found nesting in the province in 1980. In addition, the occurrence of Acadian Flycatchers *(E. virescens)* has been suspected among birds seen by DWF, ELM, and IM. Two very green-backed birds with white eye rings and forked tails, on 23 May 1977 (IM), looked particularly convincing. However, such a "difficult" species would need to be confirmed by specimen or measurements from netted birds. A supposed Acadian flycatcher noted by James Bouteillier on 31 May 1903 was of course not critically identified.

Least Flycatcher *Empidonax minimus* (P)

The status of this species is largely implicit under the previous one. The earliest spring bird identified as Least Flycatcher with confidence was on 24 May 1977, and the latest were on 20 June 1969 and 1975. The earliest identified Least Flycatcher in fall was on 25 August 1969 and the latest on 5 September 1979. James Bouteillier's bird on 20 September 1903 was probably not critically identified.

Eastern Wood Pewee *Contopus virens* (P; NSMS)

Pewees were regular and sometimes common in spring migration (Table III). There were peaks of 6-28 birds per day in 7 years during 1967-1979, on 7-12 June. They were less frequent in fall.

Olive-sided Flycatcher *Nuttallornis borealis* (P)

Although scarce, it was very regular in June (Table III). A very early bird on 25 April 1975 (AR) is the earliest recorded in the province. A bird on 25 July 1965 and 2 on 21 August 1966 were earlier than those in Table III.

Horned Lark *Eremophila alpestris* (P; AMNH)

Horned Larks occurred as migrants (Table III); the only recent winter reports were of 1 on 18 February 1971 and 2 on 24 January 1972. It may occur more regularly than indicated, as it seemed generally unattracted by buildings. The Bouteilliers reported it quite regularly in migration (Table IV), and twice in winter ("numerous" on 21 January 1904). The northern *E. a. alpestris* has been more commonly identified (includes 2 specimens in the Dwight collection), but *E. a. praticola* has also been seen and photographed.

Tree Swallow *Iridoprocne bicolor* (P)

Swallows frequented the air over ponds near West Light and perched on and around buildings, so that arrivals, departures, and peaks of abundance were readily detected. Tree Swallows generally appeared after their mid-April arrival on the mainland (Table III). Peaks of 6-70 birds occurred in every year of 1967-1979, sometimes more than once a season, between 14 May - 12 June. They arrived routinely in and lingered through June. One appeared unseasonably on 4 July 1964. In 1968 a pair stayed until 4 July, investigating inadequate, Starling-occupied holes, but not nesting. Another pair nested in a next box near West Light in July 1975, with unknown success, and 4 young were fledged from the same box in early August 1977. Fall migrants were also regular, and there were large flights of ca. 50 on 20 August 1968, 200 on 26 August 1969, and 50 on 25-27 September 1975. The Bouteilliers reported swallows frequently on their lists, but generally did not identify species. None of their observations seem seasonally remarkable.

Bank Swallow *Riparia riparia* (P)

The species was regular in spring, with small peaks of 5-20 birds occurring between 16 May and 8 June during 8 years of 1967-1979 (Table III). Most of the fall migrants were in 2 flocks, of 100 during 19-25 August 1967 and of 30 on 16-18 August 1968. The latest bird, on 21 November 1968, was injured or sick (not in Table III).

Rough-winged Swallow *Stelgidopteryx ruficollis*

One was closely observed by CB and NB on 27 August 1964, for a first provincial record. Others since were: 3 on 16 August 1966 (CB, NB), 2 on 4 August 1969 (CB, NB), 1 on 11 May 1970 (DW), and 2 on 8-16 May 1971 (JB, WS, DW). The bird has been seen and photographed elsewhere in Nova Scotia.

Barn Swallow *Hirundo rustica* (CP; AMNH, NMC)

The species was as regular and common as the Tree Swallow (Table III). Peaks of 8-40 birds occurred every year during 1967-1979, often more than once a season, as early as 1 May 1969 (when 6 of 10 died) and as late as 11 June 1974. Richard Bouteillier noted for 16 July 1907 (on MS list, but not in the published version) that: "swallows have built a nest in a barn at eastern end of Island. I am informed that one nested on the Island 20 years ago." Elliot (1956) wrote of a bird summering, but not known to be breeding, in 1948. Individuals in the late 1960's and early 1970's investigated outbuildings, but evidently did not nest. In 1975 a nest in the now demolished house at Old No. 3 Station was started around 22 June and had 2 eggs on 30 June. In 1976, 2 young were fledged from a nest in a building at Old Main Station (where there was another unexamined nest), and 5 from a shed near West Light, and 2 more nests were found in a barn near West Light. The birds also nested at Old Main and at Old No. 3 Station in 1977, but in unknown numbers and unknown success. Birds appearing after an hiatus on 13 July 1968 and 1972 were considered to be early fall migrants (Table III). Peaks of 5-50 individuals occurred during 11 years of 1967-1979 during 5-30 August. A bird on 19 November 1969 was injured (not in Table III). A completely inexplicable record was of a bird in fine weather in lively flight over the south beach on 9 February 1969 (CB, NB).

Cliff Swallow *Petrochelidon pyrrhonota* (P)

Although much scarcer than the Tree, Bank, and Barn Swallows, this species was regular in spring and fall (Table III). At times individuals lingered through June, especially in 1976 when some mud-gathering was seen, but no nests found. One appearing on 4 July 1968 was considered to be between seasons (not in Table III). An adult with a chestnut forehead, as in some southern races, was seen on 15-16 May 1972 (JB).

Cave Swallow *Petrochelidon fulva* (NMC)

One of the most extraordinary occurrences on the island was the appearance of this vagrant in 2 successive years. Five swallows that spent the cold night of 10-11 May 1968 huddled on a windowsill and 9 on 17-19 May were noted as "odd" by CB. In later May, I observed "Cliff Swallows" with pale throats and darkish rumps that did not properly impress me until I picked up a decayed but clearly identifiable Cave Swallow corpse in a small outbuilding on 21 June. In 1969 a group of 5 Cliff Swallows arrived on 13 June, and next day 3 Cave Swallows were seen close at hand, perched on a clothesline with other swallows (CB, NB, E. Garvey). Two were seen on 15 June, 2 on 20 June, and 1 on 30 June, at times with Cliff and other swallows on a clothesline (CB, NB). A specimen collected on Seal Island, Yarmouth Co., on 16 May 1971 completes the story. The species had not hitherto been found closer than southern Florida. Both specimens have been determined by Dr. W.E. Godfrey (in litt.) as belonging to the Cuban population, *P. f. cavicola.*

Purple Martin *Progne subis* (AMNH, NMC)

Martins are regular in spring and occasional in fall migration (Table III). The specimen in the Dwight collection is labelled 27 April 1899 (?1900 in the catalogue). A record of "numbers" on 20 August 1904 (Bouteillier 1905; "one" on original list) is slightly earlier than any recent fall migrants.

Gray Jay *Perisoreus canadensis*

One first seen on 5 July 1965 spent most of the following year on the island, coming to a feeder until April 1966 (CB, NB).

Blue Jay *Cyanocitta cristata* (P)

The only records were of remains of 1 on 9 June 1969, 8 between 29 May and 24 June 1970, 1 on 9 August 1970, 1 during 21-28 October 1974, 1 on 2 October and another on 14-25 October 1975, 2 on 4 June 1976, 1 on 31 May, 3 during 18-24 June, and 1 on 7-9 September 1978. The dates do not entirely coincide with the partial migrations expected in this species during early spring and late fall.

Common Raven *Corvus corax* (P)

The only records are 1 on 18-20 January 1968, 1 during 3-10 June 1974, 2 on 20 May 1975, and 1 on 16-17 October 1975.

Common Crow *Corvus brachyrhynchos* (P)

Crows were first seen in recent years by CB on 8 December 1965, and thereafter became year-round residents and nested. In late summer and fall numbers were augmented by local young and up to 5-6 occurred on the island. It is possible that migrants arrived unnoticed. A nest with 4 eggs in the now demolished barn near East Light was abandoned after discovery on 1 June 1967. A nest on top of a small dune northeast of Old No. 3 Station on 26 May 1971 had 5 eggs, and another in a like setting nearby in 1972 had 2 eggs on 12 May, 4 on 14 May, and fledged at least 1 young by 7 July. During 1967-1971, 3 crows were often seen in close association and 3 were attending the 1971 nest. Between 1977 and 1979 a trio ranged in the middle of the island and a pair near East Light, where nests were placed on the collapsed former light tower in May 1978 and 1979 (B. Beck). The bird behaved as a normal spring migrant at the turn of the century (Table IV), and evidently did not nest (Piers MS). Erskine (1953), however, stated from his 1953 visit that "one crow is said to live on the island" and next year saw a "flock of 9" in late August, which suggests that they nested on the island then.

Fish Crow *Corvus ossifragus*

A small, thin-beaked, "smoother" crow attracted attention on 12 January 1967 by chasing a gull; normally the gulls chased the crows. It was very tame, allowing CB and NB to approach within 3 m; the resident Common Crows are very wary. Its voice was a distinctly nasal "ca-ar". There are 2 winter sight records of Fish Crows (1 earlier than the Sable Island bird; see Tufts 1973) from Cape Sable Island, Shelburne Co. The species has wintered as far north as Maine, but has not been reported elsewhere in Canada. It is of course only tentatively identifiable without specimens.

Black-capped Chickadee *Parus atricapillus*

The only records are of a flock of about 10 on 26 Febuary 1967, 2 on 3-4 November 1968, and 2 on 17 May 1976.

White-breasted Nuthatch *Sitta carolinensis*

A single bird was noted on 10 May 1970, and another between 31 May and 9 June in the same year. The Bouteilliers reported it more frequently (Table IV, plus "several" on the unusual date of 3 July 1903).

Red-breasted Nuthatch *Sitta canadensis* (P)

This nuthatch was seen in most years, often lingering on and around buildings for long periods, so that arrivals and departures could be monitored (Table III). Two birds that stayed from 21 June to 22 July 1968, a bird during 1-12 July 1969, and 2 on 8-10 July 1977 were between seasons (not in Table III). Macoun (1899), beguiled by their presence at all the lifesaving stations in summer 1899, wrote that they "possibly bred on the island this year", but later (Macoun & Macoun 1909) thought not. The Bouteilliers sometimes listed nuthatches, unidentified, but assumed to be this species in Table IV. One unidentified nuthatch on 20 January 1907 (Bouteillier 1908b) was said to have been there since fall, on the original list.

Brown Creeper *Certhia familiaris*

The few sightings were of 1 on 18 May 1964, 1 on 6 July 1966, 1 on 25 September and another on 4 October 1967, 2 on 20 October 1969, 2 on 26 September 1973, and 1 on 30 October 1976. The Bouteilliers reported an earlier spring bird (Table IV).

Winter Wren *Troglodytes troglodytes* (AMNH)

The bird was occasional in spring and fall (Table III). One in late June 1967 (D. & J. Gunn) was unseasonable (not in Table III) and another on 12 December 1965 was late. The specimen in the Dwight collection was taken on 5 October 1898.

House Wren *Troglodytes aedon*

A singing male on 10 July 1965, and individuals on 2-19 July 1967 and 24-27 May 1969 (all CB, NB) are the only recent records of this vagrant. The Bouteilliers reported the species in 4 years, but these may be doubted, as they did not list Winter Wrens, although they collected one (see above species).

Long-billed Marsh Wren *Cistothorus palustris*

One was watched as it skulked among rushes of a small pond near West Light on 29 August 1964 (CB, NB). This and the Short-billed Marsh Wren are quite regular as vagrants in the province, but may be too weak-flying to reach Sable Island with the same regularity.

Northern Mockingbird *Mimus polyglottos* (P; AMNH)

An individual taken in "fall of 1894" is in the Dwight collection, yet Dwight (1903) thought it worth reporting a later bird taken on 3 September 1902 (this date is also on the specimen label, but appears to be corrected on James Bouteillier's MS list as 5 September). The Bouteilliers listed 2 other September birds (Table IV). The bird was a vagrant in the province then, but has nested in recent years and is now quite regular on the island, especially in fall (Table III). Most stayed for a few days at most, but 1 was present for more than a year, frequenting a feeder, but dying on 14 February 1967 after severe weather. One bird appeared on 7 January 1970, remained alive until at least 13 January, but was found dead on the 17th.

Gray Catbird *Dumetella carolinensis* (P; AMNH, NMC)

Catbirds were regular, although not common in fall (Table III). There were spring peaks of 5-16 individuals during 9 years of 1967-1979, between 21 May and 14 June. They often lingered well into June, especially in the (now disappearing) *Rosa rugosa* thicket at Old Main Station. One bird (not in Table III) appeared after an hiatus on 1 July 1971. A male in the Dwight collection taken 18 April 1900 and "several" on 25 April 1903 were earlier than any recent ones.

Brown Thrasher *Toxostoma rufum* (P)

Thrashers are vagrant in the province, but occurred with some regularity on the island (Table III). There were also 3 on 23 May 1965 and 1 on 2 April 1971 (not in Table III), abnormally early.

American Robin *Turdus migratorius* (P)

Considering its abundance in the region, the Robin was not very common in spring, although regular (Table III). There are no earthworms on the island, but

Robins were seen digging out larvae of June beetles *(Phyllophaga* sp.) on 1 May 1974 (DW). The fall records included large groups totalling about 200 during 3-5 November 1968 and up to 100 during 16-20 October 1975. The 2 in Table III between 31 July and 6 August 1968 were in juvenile plumage, but otherwise Robins did not appear until 28 August 1969 at the earliest. There were unseasonable appearances of single birds on 20 February 1967, 29 January 1968, and 24 February 1969. Individuals wintered in 1968-1969 (until 8 February) and in 1976-1977 (until late March). They generally appeared somewhat earlier in spring at the turn of the century (Table IV), but only 1 unseasonably early bird, on 1 March 1907, was reported. Two males on 2 April 1971 (DW) and 1 on 3 April 1972 (JB) were believed to be *T. m. nigrideus*, but others at this season were believed to be *T. m. migratorius.*

Varied Thrush *Ixoreus naevius*

A male stayed briefly around West Light on 29 October 1968, where it was well studied by CB and NB. A bird said to be like a robin with a breast band was reported by residents of the island at the Meteorological Station in October 1971, and must surely have been this species. There is an earlier sight record from the province (Tufts 1973) and it has been photographed subsequently on the mainland.

Wood Thrush *Hylocichla mustelina* (P; NMC)

This thrush, which had been a regular Nova Scotian vagrant, has nested recently in the province. During 1967-1979, it has been occasional in spring and rare in fall (Table III), with additional sightings of 1 on 31 May 1965 and 2 on 19 May 1966.

Hermit Thrush *Catharus guttatus* (P)

A few occurred every year in spring and in some falls (Table III). Generally it was later in spring than it is on the mainland, but the earliest bird, on 28 March 1968, is a provincial early record. One that appeared on 29 June 1977 (not in Table III) was between seasons. A bird on 11-12 February 1968 may have been attempting to winter in the region. Except for a single record of Veeries, this was the only *Catharus* thrush listed by the Bouteilliers (Table IV); possibly they overlooked others.

Swainson's Thrush *Catharus ustulatus* (P; AMNH)

This was the most common and regular *Catharus* (Table III), with peak spring counts of 5-20 individuals during 7 years of 1967-1979 between 23 May and 10 June. Individuals on 14 November 1967, 17 November 1968, 9 November 1969, and 10 November 1973 seem to imply a pattern of late movement in the region. However, none was a match for a bird that appeared at a feeder on 14-16 January 1969, where it was closely studied by CB and NB.

Gray-cheeked Thrush *Catharus minimus* (P)

Although less common than the preceding species, the bird was regular (Table III), with peak counts of 3-5 during 7 years of 1967-1979, between 26 May and 11 June. Individuals on 27-29 April 1969 (CB) and on 29-30 April 1977 (AR) were both earlier than any other provincial records, and a bird on 4 July 1978 was between seasons (none in Table III). As with the Swainson's Thrush, there was a small number of very late fall appearances: up to 4 on 6-18 November 1975, 2 on 13-15 November 1977, and 2 on 2-6 November 1979, all later than other provincial records.

Veery *Catharus fuscescens* (P)

This was the least frequent of the *Catharus* thrushes (Table III), with peaks of at most 3 birds during 3 years of 1967-1979, between 27 May and 10 June. Richard Bouteillier listed "numbers" on 22 October 1908 which, if correct, would be a provincial late record.

Eastern Bluebird *Sialia sialis*

The only records of this species, now rare in the province, were of 2 on 23 May 1965 and individuals on 2 September 1963, 13 May 1968, 7 June 1969, and 1 June 1970. The spring records are late for this species.

Wheatear *Oenanthe oenanthe* (P)

The only records are of individuals in female plumage on 26 May 1975 on dunes near East Light (DWF, IM et al.), and during 18-24 June 1977 near West Light (photo, HR et al.). There are no other spring records for the province.

Golden-crowned Kinglet *Regulus satrapa* (AMNH)

This species, abundant but only partially migratory on the mainland, was rare on the island (Table III), the only substantial count being 11 on 2 May 1974. The only recent fall migrant was 1 on 19 August 1966. However, the Bouteilliers reported it quite regularly (Table IV), thrice as "numerous" or "in no.".

Ruby-crowned Kinglet *Regulus calendula* (P; AMNH)

This migratory kinglet was regular in spring and fall (Table III), with peak counts of 5-30 during 7 years of 1967-1979, between 29 April and 26 May. The only comparable peaks in fall were 25 on 16-17 October 1975 and 10 on 6 September 1979. Curiously, the Bouteilliers listed it only twice, although they also reported unspecified kinglets on 3 occasions.

Water Pipit *Anthus spinoletta* (P; AMNH, NSMS)

The bird was probably even more regular than suggested in Table III, as it was "at home" away from buildings. Birds often stayed well into June, and in 1975 much flight song was given, although none stayed beyond 21 June. However, birds on 3 August 1965 and 6 August 1969 (both CB) were perhaps suspiciously early for migrants. It was regularly reported by the Bouteilliers (Table IV).

Bohemian Waxwing *Bombycilla garrulus*

Extraordinary spring and early summer sightings by CB of 2 on 21 May 1964, 3 on 16 June 1966, and 1 on 29 June 1968 are almost unique for the region. Two on 3 November 1968, becoming 20 by 9 November, presaged a major invasion of the species in the province that winter.

Cedar Waxwing *Bombycilla cedrorum* (P; AMNH)

This species is regular and common, especially in fall migration (Table III). Eight adults on 2 July 1967 were unseasonable. The earliest immature birds were on 15 August 1978. Flocks of 15-55 occurred during 7 years of 1967-1979 between 6 August and 5 November. The only winter records were 4 on 20 December 1968 and 1 on 8 February 1974. The Bouteilliers found it to be regular in fall (Table IV).

Northern Shrike *Lanius excubitor* (P; SMS)

There have been only 6 recent sightings: single birds during 16-20 October and on 28 October 1969, 1 early on 22 September 1971 (careful study, DW), 2 late on 7-9 May 1976 (AR, K. Thompson), 1 on 1 October 1976, and 1 on 20 October 1978. Another bird was found dead in late February 1974. The specimen taken 8 December 1900 was slightly later than others in Table III. Piers (MS) states: "also another shrike he feels pretty sure".

Common Starling *Sturnus vulgaris* (P)

The Starling is a regular resident, nesting in outbuildings and ruins, and recently even in stacked pipes on the beach near the severe, unstable west tip of the island. Perhaps significantly, neither Elliot (1956) nor Erskine (1953) listed the Starling after their respective visits in 1948 and 1952-1953. Birds reappeared on the island in late March or early April, after reported absences in late winter (as in 1967, 1968, 1972), or were seen sporadically or continuously through winter in some years. Sometimes there were large mortalities; of 40 estimated present in January 1979, 25 were found dead in February (AR). It is possible that some wintering birds are immigrant, as CB noted gaps between departure of post-breeding flocks in August 1967 and 1968 and the appearance of more in October of those years. Numbers sometimes reached 200 in late summer and autumn. Estimates of the adult population in May or June were 40 in 1967, 45 in 1972, 40 in 1973, 35 in 1974, 40 (including a flock of 18 nonbreeders) in 1975, 40 (including 22 nonbreeders) in 1977, and only 6 in 1979 after the big winter die-off. The first young were fledged in 9 years of 1967-1979 between 4 and 24 June (median 10 June).

White-eyed Vireo *Vireo griseus* (P)

The only record of this vagrant, increasingly noted in the province in recent years, was an adult on 15 November 1977, creeping in wet grass near West Light (IM).

Yellow-throated Vireo *Vireo flavifrons*

Three individuals of this vagrant have been seen, on the unusual date of 26 June 1964, and on 14 September and 2 October 1967 (all CB).

Solitary Vireo *Viros solitarius*

The species is inexplicably scarce on the island, with individuals recorded on 6 July 1965 and in 6 subsequent years (Table III).

Red-eyed Vireo *Vireo olivaceus* (P; AMNH)

This vireo is quite regular, especially in spring (Table III). One on 9 July 1975 (not in Table III) was between seasons. The specimen in the Dwight collection was taken on 8 October 1902, later than any recent birds.

Philadelphia Vireo *Vireo philadelphicus* (P)

A few individuals of this species, rare in the province, have occurred between 1967 and 1979 (Table III).

Warbling Vireo *Vireo gilvus*

Individuals have occurred on 22 June 1964, 31 May 1966 (both CB), 12-13 June 1967 (D. & J. Gunn), 4-6 June (CB) and 13 June 1969 (JB), and 12 November 1977 (IM), the last a latest record for the province. Most records of this vagrant in the province are for fall.

Black-and-white Warbler *Mniotilta varia* (P; NMC)

The species is regular and common, spring and fall (Table III). Two earlier birds were discovered recently dead in late April 1977. Daily counts of 5-10 birds were made during 6 years of 1967-1979 between 23 May and 7 June. Larger counts of 10-20 occurred during 4 autumns, between 30 August and 30 September. The Bouteilliers noted it only in fall (Table IV).

Prothonotary Warbler *Protonotaria citrea* (P; NMC)

The species has been a rather regular vagrant in fall (Table III). An exceptionally early bird (along with an Ovenbird and a Wilson's Warbler) appeared on 18 April 1971 (JB, WS; not in Table III). Another on 4 July 1965 was between seasons. The record given in Tufts (1973) is misdated and misattributed: the date given is for the next species. James Bouteillier reported "several" on 7 September 1903, close to the present median dates (cf. Table III). A marginal note on the MS by Piers states "Not before in N.S. App. Mr. Bouteillier not sure of this"; this may be gratuitous in view of the bird's distinctness.

Worm-eating Warbler *Helmitheros vermivorus* (AMNH, NMC)

The specimen in the Dwight collection was a male taken on 3 October 1903, but not reported in the literature. Dwight (1903) did not mention it, which is surprising, since he included several birds that must have been sent to him at the same time, including a "Baltimore Oriole" taken on 4 October 1902. The specimen appears to be a first Canadian record (cf. Saunders 1908). One on 12 October 1967 (CB, NB.) was a second Nova Scotian record, a number having been seen since in the province. A desiccated corpse, some weeks dead, was found on 7 June 1978.

Blue-winged Warbler *Vermivora pinus*

An early individual of this vagrant appeared on 14 April 1975, along with an equally unexpected Yellow Warbler (AR). Most of the few provincial records are for late summer or fall.

Tennessee Warbler *Vermivora peregrina* (P)

The species was regular, generally in ones and twos. Spring counts of 5 on 2 June 1968, 8 on 10 June 1974 and 6 on 24 May 1977 were exceptional, as were 5 on 13 September 1977, 10 on 28 August and 8 September 1978, and 15 on 6 September 1979. A bird on 4 July 1969 was between seasons (not in Table III).

Orange-crowned Warbler *Vermivora celata* (P)

Individuals of this uncommon Nova Scotian transient have been reported on 6 June 1964 (CB), on 18 May (CB) and during 14-18 June 1967 (D. & J. Gunn); on 28 September (2 individuals), 31 October, and 10 November 1967 (all CB); on 1 June 1969 (CB), between 31 May and 11 June 1974; on 26-30 May, 4 June, and 22 June 1975 (DWF et al.).

Nashville Warbler *Vermivora ruficapilla* (P)

This species, although common on the mainland, was scarce on the island (Table III).

Northern Parula Warbler *Parula americana* (P)

This species was regular in spring, but decidely rare in fall (Table III). Spring occurrences were always in ones and twos, except for a count of 20 on 7 June 1968.

Yellow Warbler *Dendroica petechia* (P)

Yellow Warblers occurred in both spring and fall in some numbers (Table III). One on 14 April 1975 (AR) was exceptionally early (not in Table III). In spring they generally occurred in ones and twos, but there were exceptional counts of 8 on 9 June 1969, 10 on 25 May 1971, and 8 on 10 June 1974. In fall, there were 8 on 8 August 1971, 25 on 8 September 1978, and 15 on 27 August 1979. The Bouteilliers reported them a bit later in spring (Table IV).

Magnolia Warbler *Dendroica magnolia* (P;AMNH)

The bird occurred regularly in spring and fall (Table III); the earliest seen, a male on 7 May 1968, is a provincial early record. There were peak counts of 5-15 during 8 springs of 1967-1979, between 3 and 15 June; maximal fall counts were 5 on 12 September 1972 and 10 during 10-18 September 1973.

Cape May Warbler *Dendroica tigrina* (P)

This species was scarce during most springs, but sporadically common in fall

(Table III). There were, for example, large counts of 20-60 during 7 years since 1969 between 27 August and 19 September. A bird appearing on 2 July 1968 was between seasons.

Black-throated Blue Warbler *Dendroica caerulescens* (P)
This was the least common of the warblers that nest in Nova Scotia (Table III). A male on 4 July 1969 was between seasons (not in Table III). The Bouteilliers recorded only 3 birds (Table IV).

Yellow-rumped Warbler *Dendroica coronata* (P; AMNH, NMC)
As might be expected, this species was among the most regular and abundant landbird migrants (Table III). Peak counts of 15-100 were made during 7 springs of 1967-1979 between 1 May and 1 June. Unlike other less common warblers it seldom lingered in numbers past mid-June. Counts of 30-300 were made during 11 falls of 1967-1979 between 15 August and 16 November. Birds appeared routinely in December and apparent winter arrivals were: up to 5 between 24 December 1969 and 1 January 1970, 1 on 24 January 1972, 6 during 7-20 February 1974, and up to 14 wintered in 1978-1979. An oddly plumaged male with white and yellow upper flanks and a white chest and nape was photographed on 18 May 1977 (IM). An adult male of the western "Audubon's Warbler" (*D. c. auduboni*, or *D. c. memorabilis*) was closely observed among "Myrtle Warblers" on 4 May 1967 (CB, NB). This was a first record for Atlantic Canada.

Black-throated Gray Warbler *Dendroica nigrescens*
There were 2 sight records of this western vagrant, not previously reported east of Ontario in Canada, although known in coastal New England. Both were males seen by CB and NB, the first in shrubs near West Light on 9 May 1966, and the second closely observed on a windowsill feeder on 1 May 1967. There are 2 subsequent fall records from Nova Scotia.

Townsend's Warbler *Dendroica townsendi* (P)
A female was closely studied on 9-10 June 1973 (JB, DWF, IM) for a first record from Atlantic Canada. There are no subsequent records from the province.

Black-throated Green Warbler *Dendroica virens* (P; AMNH)
The bird was regular in spring, less so in fall (Table III). Up to 4-5 were counted during 4 springs of 1967-1979, between 29 May and 4 June. At most 1-2 occurred per day in fall, except for a count of 9 on 12 September 1972. The male on 4 May 1971 is the earliest spring record from the province.

Hermit Warbler *Dendroica occidentalis* (P)
Among the most unusual vagrants was a female Hermit Warbler on 26-27 May 1975 (DWF, EHM, IM) and another female on 4 June (DWF), identifiably different on photographs (Fig 14). These birds, from the western mountains of the United States, were the first to be confirmed from Canada (sight records in British Columbia), although known earlier from New England.

Cerulean Warbler *Dendroica cerulea*
An adult male observed outside a window at 2 m on 6 June 1968 (CB, NB) was the first documented from the province (see Tufts 1973 for possibly earlier sightings). Another less-than-full-plumaged male was seen on 20 May 1972 (JB, DW).

Blackburnian Warbler *Dendroica fusca* (P)
Although quite regular, the bird was uncommon (Table III), the largest count being 4 on 10 June 1974. The male on 10 May 1967 is the earliest on record from the province.

Yellow-throated Warbler *Dendroica dominica* (P)

There have been occurrences of individuals in recent years, all near West Light or the Meteorological Station. One seen briefly at close range on 7 June 1968 (CB) was a first for the province, and another photographed that summer on 22 August (D. Higgins) was a first authenticated record. Others were seen by AR on 25 October 1974, 12 September 1975, 26-28 September 1976 (2 birds), and during 20-25 September 1977 (2 birds).

Chestnut-sided Warbler *Dendroica pensylvanica* (P)

The species is quite uncommon on the island (Table III), and was not reported by the Bouteilliers.

Bay-breasted Warbler *Dendroica castanea* (P)

The species was quite common in spring, rarely lingering in June, and returning in some numbers in fall (Table III). Two birds on 7-8 May 1969 are the earliest on record from the province. Although 25 were estimated to be present on 7 June 1968, there were otherwise never more than 5 per day in spring. Counts of 5-24 birds were made during 5 falls of 1967-1979, between 28 August and 16 September. It is noteworthy that the Bouteilliers never reported this species or the Cape May Warbler, both responsive to outbreaks of spruce budworm.

Blackpoll Warbler *Dendroica striata* (P; AMNH, NMC)

This, next to the Yellow-rumped Warbler, is the most regular and common warbler on the island (Table III). Peak counts of 10-90 occurred in 11 years during 1967-1979 between 24 May and 12 June. An adult male on 14 July 1968 was early (not in Table III). Counts of 13-120 birds were made in 6 years between 5 September and 16 October. About 50 were killed by collision with West Light on the night of 5-6 October 1964, and 16 met the same fate on 15-16 October 1969. A bird on 13-15 December 1968 was late (not in Table III), and an individual frequented a feeder between 1 January and 4 February 1969, where it was closely studied by CB and NB; it was a first winter record for the province. All the Bouteilliers' records are for spring (Table IV), and it is probable that they did not correctly identify autumn blackpolls (see under Pine Warbler). A mysterious bird listed as "Black-bellied Warbler" on 26 May 1904 by Bouteillier (1905) is in fact "Black polled Warbler" on the original list.

Pine Warbler *Dendroica pinus*

Nine individuals of this vagrant have been reported in recent years: 1 on 27 May 1964 (CB), 2 during 2-10 June 1967 (CB, NB, J. Gunn), 1 on 10 October and another on 2-6 November 1967 (both CB), 1 on 15 November 1968 (IM), 1 on 7 September 1970 (WS), 1 on 10 September 1974 (B. Mactavish), and an early adult male on 12-14 August 1978 (HR). The quite frequent reports by the Bouteilliers of this species must be viewed skeptically, as they failed to report autumn blackpolls. Furthermore, James Bouteillier reported a Pine Warbler, and no Blackpoll Warbler, on 3 June 1902, and there is a female specimen of the latter species in the Dwight collection from this date.

Prairie Warbler *Dendroica discolor* (P)

Praire Warblers are now among the most regular vagrants to the province since the first reported sighting of a bird on Cape Breton Island in September 1964. The second was on Sable Island on 2 August 1965 (CB, NB), still the earliest fall migrant recorded in the province. They have since occurred every year except 1966, 1967, and 1976 (Table III), always as fall migrants.

Palm Warbler *Dendroica palmarum* (P; AMNH)

The bird has been regular in small numbers in spring, with somewhat more in fall (Table III). The largest count in spring was 10 on 22 May 1972. Counts of 10-20 occurred during 3 falls of 1967-1979, between 16 October and 5 November. Two birds appeared on 28 December 1969 and 1 remained until 9 January 1970 (not in Table III). Oddly, the Bouteilliers listed the species only for fall (Table IV), although there is a spring male of *D. p. hypochrysea* in the Dwight collection.

Ovenbird *Seiurus aurocapillus* (P)

The species was regular in ones and twos (5 on 30 May 1975 were exceptional), and not so frequent in fall (Table III). One on 18 April 1971 (with early Prothonotary and Wilson's Warblers) was later found dead, and another on 27 April 1977, joined by another on 29 April, are all earlier than any other provincial records (none in Table III). One on 16 July 1976 was unseasonable in summer (not in Table III).

Northern Waterthrush *Seiurus noveboracensis* (P; AMNH)

The bird was regular in spring and fall (Table III). There were peak counts of 5-32 birds during 8 springs of 1967-1979 between 19 May and 6 June. In fall, peaks of 4-20 birds were noted during 5 years of 1967-1979 between 24 August and 12 September. The Bouteilliers listed it only once in spring and twice in fall migration.

Louisiana Waterthrush *Seiurus motacilla* (P)

One closely studied on the rather unusual date of 2 July 1966 (CB, NB) was a first for Nova Scotia. Subsequently 7 have been reported: 1 on 3-4 August and another between 21 August and 2 September 1969 (both CB, NB), 2 during 6-10 August 1970 (JB, WS, DW; Fig 15), 1 on 27 May 1971 (DW), 1 on 18-20 May 1977 (IM, HR), and 1 on 8 September 1978 (IM). The bird has been reported elsewhere in the province since 1969.

Kentucky Warbler *Oporornis formosus* (P; AMNH)

The immature bird collected on 1 September 1902 (Dwight 1903) was a first from the province. Males on 1-4 June and 22-23 June 1976 (both AR) and a female on 2 September 1978 (IM) are among the few recent reports from the province.

Connecticut Warbler *Oporornis agilis* (P)

Reports of a dead bird on 6 October 1901 (Bouteillier 1901) and of a bird sighted on 15 September 1907 (Bouteillier 1908b) have been questioned (Godfrey 1966; Tufts 1973); the Bouteilliers reported no Mourning Warblers. A male was closely observed on 10 September 1974 (B. Mactavish) and a female was photographed, for a first authenticated provincial record, on the extraordinary date of 12 June 1975 (DWF). An immature bird was well-studied during 9-13 September 1978 (IM).

Mourning Warbler *Oporornis philadelphia* (P)

Small numbers appeared with remarkable regularity in early June, but the species was rare in fall (Table III). Only twice did more than 2 occur at a time: 6 on 10 June 1974 and 3 on 7-8 June 1975. Earlier records of a bird on 17 May and 2 on 28 May 1965 were exceptional.

Common Yellowthroat *Geothlypis trichas* (P; AMNH)

Yellowthroats were regular in spring, generally in ones and twos (Table III). Counts of 5-8 birds were made during 6 springs of 1967-1979, between 22 May and 7 June. It was uncommon in fall, a count of 6 on 16 October 1975 being the only occasion when more than 1-2 birds were seen.

Fig 14 Photographs confirmed what was suspected in the field—that female Hermit Warblers on 2 dates in spring 1973 were different individuals, the first in eastern Canada of this species from the Coast Range of the western United States. (Photos: left, 26 May, right, 4 June 1973, D.W. Finch.)

Fig 15 A representative vagrant warbler from the eastern United States, a Louisiana Waterthrush, was captured in an outbuilding for a first authenticated provincial record. (Photo: 9 August 1970, J. Burton.)

Yellow-breasted Chat *Icteria virens* (P; NMC)

The first island record was on 25 August 1963, the next on 20 August 1965, and the bird has been routine in fall since 1966, although never as early as these first 2 reports (Table III).

Hooded Warbler *Wilsonia citrina* (P; UM)

The first island record of this vagrant was 1 on June 1964, and 2 were seen on 23 May 1966. It has been quite frequent since (Table III). Three birds on 2 July 1967 (CB, NB) were unseasonable (not in Table III).

Wilson's Warbler *Wilsonia pusilla* (P; AMNH)

The bird was regular in spring, often arriving late, and somewhat less common in fall (Table III). Counts of 5-11 birds were made during 7 years of 1967-1979, between 23 May and 14 June. A bird on 18 April 1971 (JB, WS) was exceptionally early (not in Table III). Counts of 4-10 birds were made only during 3 years in fall, between 13 August and 22 September.

Canada Warbler *Wilsonia canadensis* (P; AMNH)

Next to the Mourning Warbler, this was the latest of the regular warblers in spring (Table III). It was generally in ones and twos, with counts of 6-20 birds during 4 years of 1967-1979, between 28 May and 10 June. A count of 25 on 16 June 1964 was exceptional. One on 2 July 1967 was unseasonable (not in Table III).

American Redstart *Setophaga ruticilla* (P; NSMS)

Although not among the most abundant, this was among the most regular and conspicuous warblers, and often lingered on the island (Table III). It peaked late in spring, with counts of 5-17 birds during 7 years of 1967-1979, between 31 May and 15 June. A bird on 3 May 1975 (not in Table III) ties the earliest provincial record. One on 3 July 1971 (not in Table III) was between seasons. There were peak counts of 8-40 birds during 9 years of 1967-1979, between 5 September and 20 October.

House Sparrow *Passer domesticus* (P)

The Bouteilliers listed first seasonal sightings quite regularly (Table IV) and Bouteillier (1905) noted that 2 birds had overwintered. Dates of appearance do not coincide with supply boats (Nova Scotia Archives). Richard Bouteillier (Piers MS) thought that they first appeared 2-3 winters prior to 1901. Evidently they did not nest until much later. Elliot (1956) learned from old residents that sparrows had nested "at least since 1930". Estimates of about 60 birds around West Light in early June 1967 and about 60 around the Meteorological Station on 28 December 1969 match quite well the estimates of about 150 in the 2 localities in September and November 1970 (JB). With the elimination of chickens from the island in late 1970, food for House Sparrows was curtailed, and they died off and perhaps to some extent emigrated. Transient birds have occurred since: a female on 24 October 1971 (DW), 2 on 9 May 1975 (AR), 2 between 24 April and 4 May 1977 (AR), and 5 on 20 October 1978 (IM). These records resemble those from the turn of the century, and seem to reveal the sparrow as a partial, but seasonally normal migrant, and still capable of colonizing across a considerable water barrier. The species is unlikely, however, to recolonize the island in the absence of grain-fed livestock.

Bobolink *Dolichonyx oryzivorus* (P)

Bobolinks were regular in spring (Table III), the males often singing around ponds near West Light for several days. Generally they occurred in ones and twos, but there were counts of 6-11 birds during 5 years of 1967-1979, between 23 May and 5 June. A male on 28 April 1964 was very early. They were less regular in fall, perhaps because they frequented the dunes then. During censuses of Ipswich Sparrows on high dunes in early September (Table V), counts of 37-115 birds were made, implying as many as ca. 1700 on the island.

Eastern Meadowlark *Sturnella magna* (AMNH)

There are only 4 recent records of this species, which is uncommon in Nova Scotia: on 28 September 1970, 20 September 1971, 5 March 1977 (eating bread at West Light; AR), and on 5 January 1979 (AR). A specimen was taken on 6 May 1901.

Yellow-headed Blackbird *Xanthocephalus xanthocephalus* (P)

A bird on 5 October 1901 (Bouteillier 1901) was a first record for the province, and another was seen next year on 16 September by James Bouteillier. A photograph of a female (not on file NMC) on 12 October 1967 (CB) was accepted by Tufts (1973) as a first authenticated record. A female between 8-17 May 1970 (AL, WS et al.) was a first spring record for the province. There have been birds subsequently every year since 1973 except 1976 (Table III).

Red-winged Blackbird *Agelaius phoeniceus* (P; SMS)

The species was regular but scarce in spring, generally later than on the mainland (Table III). A male appeared on 26 June 1971 and sang around ponds near West Light until 4 July; another was seen on 5 July 1977 (neither in Table III). Large daily counts of 20-120 birds were made during 1967-1979 between 3 October and 18 November, but only ones and twos have occurred in more recent falls.

Orchard Oriole *Icterus spurius* (P; ROM)

A young male taken by Saunders (1902) on 15 May 1901 was one of the earlier records from Nova Scotia. Thirteen individuals of this now regular vagrant have occurred in recent years, beginning with a female on 31 May and an adult male on 5 June 1965 (both CB, NB), and during most years since (Table III). The late spring and late fall birds (Table III) are the latest on record for the province for their respective seasons. Bouteillier (1901) listed a bird on 28 September 1901, and James Bouteillier reported them "in no." on 4 October 1902. However, the latter record, at least, is questionable, since Dwight (1903) obtained a specimen of a Northern Oriole from this date (not in AMNH or SMS).

Northern Oriole *Icterus galbula* (P; NSMS)

The bird was relatively scarce in spring, but regular and common in fall (Table III). A bird on 25 July 1971 was considered to be unusually early (not in Table III). Large counts of 12-35 birds were made during 8 years of 1967-1971, between 1 September and 5 October. Probably most autumn birds come from outside the province, where they nest sparingly. They often attempt to winter in the province; the latest bird died on 18 December 1967.

Rusty Blackbird *Euphagus carolinus* (P; AMNH)

The species was regular in spring, but the bulk of the individuals (Table III) were in flocks of ca. 100 on 12 April and 17 May 1968. Such flocks were more regular in fall, when groups of 35-100 occurred during 4 years between 1 October and 24 November. A male appearing briefly on 4 January and another on 23 January 1969 had probably been wintering in the region, but 2 males on 7-10 March 1967 and another on 9 March 1968 (not in Table III) may have been early immigrants. The Bouteilliers reported it twice in September, but more often listed unidentified blackbirds.

Brewer's Blackbird *Euphagus cyanocephalus*

A glossy male, with purplish head, quite distinct from male Rusty Blackbirds at this season, appeared on 30 November 1969 (CB, NB). It was apparently injured at first, but soon recovered and came to a feeder regularly until late March 1970, when it was also seen by AL. The species has been seen occasionally elsewhere in the province during recent years.

Boat-tailed Grackle *Quiscalus major*

A male, much larger than the Common Grackles present during the period, and with a huge, keeled tail and distinct iridescence pattern, was seen around West Light during 7-10 May 1968 (CB, NB). This was a first Canadian record, subsequent sightings having come from Cape Breton Island and Cape Sable Island, Nova Scotia.

Common Grackle *Quiscalus quiscula* (P)

Except for 33 on 23 April 1967 (and a like group on 22 April 1964), this grackle was uncommon in spring and even more so in fall (Table III). Two on 28 December 1968 and 6 on 12 January 1974 had probably wandered from the nearby mainland, where they attempt to winter.

Brown-headed Cowbird *Molothrus ater* (P)

The cowbird is one of the island's most regular and common passerine visitors (Table III). Counts of 10-15 (sometimes single flocks) were made during 5 springs of 1967-1979, between 4 April and 4 May, and during 6 falls, between 3 August and 6 December. A fledged young was being fed by an Ipswich Sparrow on 3 July 1963. In 1968 a male and 2 female Cowbirds parasitized at least 3 nests of Ipswich Sparrows (Stobo & McLaren 1975). Fledglings were seen on 6 July and 3 independent young were noted in early August of that year. There is no indication that a female on 11 July 1971, 2 males on 5-6 July 1977, and a male on 7 July 1979 (none in Table III) had bred locally. Six birds appearing on 16 December 1968 stayed until 4 February 1969, and 10 on 28 December 1969 remained in dwindling numbers until 13 February 1970. Five between 22 February and 3 March 1969, 1 remaining until 15 March, were unseasonable wanderers (none in Table III). The Bouteilliers noted none of this rather recent invader of the province.

Scarlet Tanager *Piranga olivacea* (P; ROM)

This tanager, a routine vagrant to the province, was occasional on the island (Table III). There was a notable count of 9 widely scattered birds on the island on 12 September 1972. A male on 6-7 December 1969 (CB) was abnormally late (not in Table III).

Summer Tanager *Piranga rubra* (P; NMC)

Adult males on 29 August 1964 and 25 August 1967 (both CB, NB) and a female or young bird on 13 September 1972 (IM et al.) are the only recent records. (The specimen is a subadult male found by AR on 6 May 1980, beyond the period otherwise covered in these accounts.)

Rose-breasted Grosbeak *Pheucticus ludovicianus* (P; NMC)

This regular visitor occurred annually in spring and most falls (Table III). It was often early on the island, in comparison with usual arrival dates on the mainland. The largest daily counts were 5 on 17 May 1969 and 4 during 16-20 October 1968.

Black-headed Grosbeak *Pheucticus melanocephalus*

An adult male was closely observed by AR near West Light on 18-19 September 1978. There have been about 5 sightings and a photographic record in the province.

Blue Grosbeak *Guiraca caerulea*

A female on 28 April (JB, WS) and 2 males on 5 May 1971 (WS) were part of that season's larger-than-usual flight of this species to the province. An immature bird was seen on 1 September 1978 (ELM).

Painted Bunting *Passerina ciris*

A bright adult male perched on a wire near West Light was well observed on 31 July 1965 (CB). An all-green finch, the size and shape of an Indigo Bunting, was reported by E. Androschuk in early September 1969. Previous Canadian records have been categorized as probable "escapes" by James et al. (1976).

Indigo Bunting *Passerina cyanea* (P; NMC, SMS)

This regular vagrant to the province occurred in most springs and occasionally in fall (Table III). A specimen in the Dwight collection taken on 18 April 1898 was earlier than any recent birds (cf. Table III).

Dickcissel *Spiza americana* (AMNH, NMC)

The first record from the province was a specimen from 12 September 1902 (Dwight 1903). In recent years it has been irregular on the island (Table III), but occurred in some numbers at times: e.g. 5 on 5 October 1967, 12 on 22 October, and 8 on 13 November 1969. Records of a female between 28 June and 1 July 1968 and a male on 24 June 1970 are later than any of the few spring records for the province. Late-fall birds on Table III frequented feeders. Two males appeared on 20-21 February 1970.

Evening Grosbeak *Hesperiphona vespertina* (P; NMC)

This species was recorded most years during migration seasons (Table III). Generally it appeared as individuals or small groups; exceptions were flocks of 65 on 4 November 1968 and 120 on 20 October 1978. About 24 birds appeared periodically at feeders in the winter of 1968-1969, when there were large flights of this and other winter finches across the continent. Otherwise only about 7 individuals were reported during 3 winters of 1967-1979.

Purple Finch *Carpodacus purpureus* (P)

The species was a regular and common spring and fall migrant (Table III). The only winter report was of a bird in female plumage on 8 January 1970.

Pine Grosbeak *Pinicola enucleator* (P; AMNH, SMS)

The species occurred occasionally during migration seasons (Table III), and only once (a bird on 9-14 January 1979) as a winter visitor. "Several" seen by James Bouteillier on 21 November 1903 were later than any fall migrants in Table III.

Hoary Redpoll *Carduelis hornemanni*

A single bird was briefly but closely observed on the unusual date of 18 May 1977 (IM, HR).

Common Redpoll *Carduelis flammea* (P; NMC, SMS)

Redpolls were irregular (Table III); only 2 substantial flocks have been reported, of 45 on 29 April 1964 and 30 on 24 April 1969. The only recent winter sightings were of 3 between 2 January and 20 February 1969, and 6 during 1-15 March 1978. Bouteillier (1905; 1908b) listed 2 winter occurrences. Most unexpected was their occurrence in summer 1968: 3 on 6 July and a single bird or birds between 12 July and 3 August (CB, IM).

Pine Siskin *Carduelis pinus* (P; AMNH, NMC)

Siskins were regular in spring, often lingering through June (Table III). Four birds appeared unseasonably during 6-12 July 1968 and 1 on 6 July 1978 (not in Table III). They were regular after mid-July, however, and unusually large flocks (total ca. 50) appeared on 19 July 1968 and in diminishing numbers until early August. Interestingly, the Bouteilliers noted it twice in early July (not in Table IV). The only winter records were 2 between 23 February and 7 March and 1 or 2 in late March 1969.

American Goldfinch *Carduelis tristis* (P; AMNH).

Goldfinches were generally scarce in spring and fall. An extraordinary exception was a flight of many flocks, estimated by DW as 2000 on the whole island, on 24 October 1971 (not in Table III); only 15 were seen next day. An individual observed between 27 June and 14 July 1968 and a pair on 5 July 1969 were unseasonable (not in Table III).

Red Crossbill *Loxia curvirostra*

This species was quite rare. Two were present between 23 June and 3 July 1964, 3 on 16 August 1966, 3 between 27 June and 19 July and 4 between 15 October and 4 November 1968, 5 on 5 July and 5 during 7-26 August 1969, 7 on 21 September 1971, and 1 on 14-16 August 1975.

White-winged Crossbill *Loxia leucoptera* (P)

The bird was rare in spring and scarce in fall (Table III). Like the Red Crossbill, it appeared most often in summer: 3 on 11 July 1965, 1 on 8 July 1968, 5 on 14 July 1969, 1 during 3-9 July 1976, 3 on 7 July 1977, and 3 during 3-12 July 1978 (none on Table III). These records, along with the late June and early August records (Table III) reflect a seasonal movement of the species separate from sightings otherwise only in November-December.

Green-tailed Towhee *Pipilo chlorurus* (P)

A bird on 10-12 June 1974 was the third Nova Scotian record of this vagrant (DWF; Fig 16), the second having been photographed 3 weeks earlier on Seal Island, Yarmouth Co.

Rufous-sided Towhee *Pipilo erythropthalmus* (P)

Individuals of this regular vagrant to the province occurred on 5 June 1964, 6 October 1966, and regularly during 1967-1979 (Table III). An exception to the usual occurrence of single birds were 4 on 16 May 1971 and about 20 during 6-12 October 1974.

Savannah Sparrow *Passerculus sandwichensis* (AMNH, NMC, NSMS, ROM, SMS, UM)

The Ipswich Sparrow (*P. s. princeps;* Fig 17) is of course the breeding race of this species, and has been extensively studied by Dwight (1896), Elliot (1968), and by my students and myself (see Recent Research on Birds). Between 1150 and 3300 adults have returned each year since 1967, producing late-summer populations of 3500-14000. Up to a few hundred sometimes attempt to winter. Migrants of the smaller, darker race(s) occurred in small numbers in spring and fall (Table III). One was seen on 20 January 1972 (JB). A few, mostly males, have been found mated to Ipswich Sparrows on the island. A specimen of 1 of these is of the expected race, *P. s. savanna* (Dr. W.E. Godfrey, in litt.). One banded offspring of a ♂Savannah X ♀ Ipswich mating returned to the island in 1978 when 1 year old (H. Ross, in verb.).

Fig 16 The province's third (and the island's only) Green-tailed Towhee, a vagrant from the southwestern United States, was found at the Meteorological Station. (Photo: 10 June 1974, D.W. Finch.)

Fig 17 The island's most famous avian inhabitant is the Ipswich Sparrow, a large, pale race of the Savannah Sparrow. (Photo: early April 1971, I. McLaren.)

Grasshopper Sparrow *Ammodramus savannarum* (NMC)

Fragments of a bird in autumn plumage (Dr. W.E. Godfrey, in litt.) were found in spring 1972, and individuals were seen on 23 October 1973 and 20 October 1978 (both IM). The bird is a regular autumn vagrant in the province.

Henslow's Sparrow *Ammodramus henslowii*

Records of "several" on 18 May 1905 and 16 May 1906 (Bouteillier 1906; 1908a) should perhaps not be rejected entirely, in view of the island's reputation. There have been 2 recent autumn sightings elsewhere in the province.

Sharp-tailed Sparrow *Ammospiza caudacuta*

Two were seen on 9 September 1964 and single birds on 29 November 1970 and 3 June 1974. The 1964 birds were noted by CB as having brown, white-streaked backs and well-streaked breasts; the possibility of southern or inland races is suggested.

Seaside Sparrow *Ammospiza maritima*

One seen around ponds near West Light on 10 May 1970 (DW) was the first spring record of this occasional fall-winter stray to the province.

Vesper Sparrow *Pooecetes gramineus* (SMS)

There have been only 4 recent reports. A number occurred on 4 May 1964 and an individual on 14-20 May 1972. Up to 50 birds during 7-14 October 1967 (CB) occurred during the season when the species is regular in coastal Nova Scotia, but not in such numbers. One was seen on 17 October 1975. The Bouteilliers reported it on occasion (Table IV), "in no." on 27 April 1903, and as late as 25 December 1903 (not in Table IV).

Lark Sparrow *Chondestes grammacus* (P; AMNH)

The first provincial record of this vagrant from the midwest was from Sable Island (Dwight 1903), a specimen labelled 4 September 1902, possibly the same bird listed by James Bouteillier for 6 September. "Several" were listed for 10 October 1902. In recent years there have been 1 on 3 August 1965, 1 on 29 August and another on 16 September 1969, 1 on 24 September 1970, 1 on 29 August 1977, and 1 on 8 September 1978, all from the usual season. A bird on 18 May 1970 (DW) was a first spring record from the province.

Dark-eyed Junco *Junco hyemalis* (P; AMNH)

Most spring occurrences (Table III) were of 1 or a few individuals, but flocks of 10-30 occurred during 7 years of 1967-1979, between 2 April and 14 May. Larger counts of 20-50 were made during 6 falls, between 14 October and 1 December. About 20 appeared on 20 February 1967, 3 on 10 February 1968, 2 in early January 1969, and 1 on 30 January 1978 (none in Table III). The species was listed every year by the Bouteilliers, with first spring arrivals quite similar to those in recent years (Table IV). One on 28 June 1902 was later than any in recent years. Their fall arrivals were later than in 1967-1979. A dark-hooded male "Oregon Junco" was reported by residents of the Meteorological Station several times during the winter of 1972-1973, and another was seen on 29 September 1975 (AR). Another on 16-17 October 1975 (IM) was apparently of the "pink-sided" *mearnsi* race.

Tree Sparrow *Spizella arborea* (P)

The species was scarce in spring and fall (Table III), and was not seen in winter. Three on 18 April 1966 were as early as the earliest in recent years.

Chipping Sparrow *Spizella passerina* (P; SMS)

The species was scarce in spring and fall (Table III), and never occurred out of season.

Field Sparrow *Spizella pusilla*

James Bouteillier's listing of "several" on 4 October 1902 is the earliest reference to this vagrant in the province. In recent years 9 individuals have been reported: on 21 August 1964, 2 June 1966, during 15-28 May 1966, on 24 and 29 May 1970, on 2 and 16 May 1971, 14 October 1971, and 5 September 1978.

White-crowned Sparrow *Zonotrichia leucophrys* (P; AMNH)

The species is quite regular on the island, even in spring, when it is scarce on the mainland (Tables III, IV). One immature bird appeared in November 1968 and came to a feeder until 7 March 1969 (not in Table III); this was the first winter record from the province. An individual of the western race *gambelii* was observed on 25-28 May 1969 (CB et al.) and photographed in early June by D. Higgins, to confirm it adequately as this race (W.E. Godfrey, in litt.). The only other provincial *gambelii* have been seen in fall.

Golden-crowned Sparrow *Zonotrichia atricapilla*

An adult bird was closely observed near West Light on 9 October 1967 (CB, NB) for a first provincial record. There has been a subsequent photographic record from the mainland.

White-throated Sparrow *Zonotrichia albicollis* (P; AMNH, NMC)

This species was regular and common, but generally arrived later in spring than it does on the mainland (Table III). Counts of 20-90 birds occurred during 8 springs of 1967-1979, between 27 April and 31 May. Counts of 10-100 occurred in fall between 12 September and 1 November. One bird between 25 January and 6 February 1969 was an evident winter arrival, and another on 13 March 1973 was too early for a normal migrant (not in Table III). It was reported thrice by the Bouteilliers, on arrival dates comparable with recent ones (Table IV).

Fox Sparrow *Passerella iliaca* (P)

Fox Sparrows were regular and at times common in spring and fall (Table III). Counts of 35-60 were made during 3 springs of 1967-1979, between 2 and 19 April. Counts of 15-50 were made in 3 falls, between 26 October and 5 November. The Bouteilliers reported it frequently, and at similar times of year (Table IV).

Lincoln's Sparrow *Melospiza lincolnii* (P; AMNH)

The bird was regular in spring, less so in fall (Table III). Counts of 5-21 birds were made during 3 springs of 1967-1979, between 26 May and 10 June. A bird during 16-26 June 1971 was injured (not in Table III). One of the 2 specimens in the Dwight collection is labelled 30 June 1894, later than any recent ones.

Swamp Sparrow *Melospiza georgiana* (P; AMNH)

The species was regular in spring, less so in fall (Table III), generally appearing later in spring than it does on the mainland. Counts of 5-13 birds were made during 5 springs of 1967-1979, between 18 May and 2 June. The only such counts in autumn were 10 on 24 October 1973 and 15 on 16 October 1975.

Song Sparrow *Melospiza melodia* (P; NMC, SMS)

The species was regular in small numbers in spring, and infrequent in fall (Table III). Only once did more than 8 occur: a flight of ca. 100 on 4 April 1971. They were listed only once at the turn of the century, as "numerous" on 20 March 1904, earlier than recent records. In 1977 a pair nested in the deep grass inside a fence of a house at the Meteorological Station. A nest with 4 eggs was found on 31 May; 4 fledged young were seen on 10 July, and a fledgling on 4 August was clearly from a second brood (HR et al.).

Lapland Longspur *Calcarius lapponicus* (P; AMNH)

The bird was reported infrequently in spring and irregularly in fall (Table III), perhaps because observations were seldom made on dunes remote from buildings. The only large counts were up to 150 during 3-5 November 1968 and ca. 20 on 17 October 1975. The only winter sightings were of individuals on 7 January 1964, 18 February 1966, 9 February 1969, and of 4 on 21 January 1972.

Chestnut-collared Longspur *Calcarius ornatus*

A rather wary bird in female plumage on 9 June 1977 had all field marks of this prairie species (HR). Oddly, the species has occurred several times in late spring in Atlantic Canada.

Snow Bunting *Plectrophenax nivalis* (P; AMNH)

At times abundant on the island, it often lingered into May (Table III). Large counts were made by people ranging widely on the island in fall (e.g. 150 on 3-5 November 1968, 800 on 19 November 1970, 100 on 5 November 1973). Winter sightings (not in Table III) totalled some 1000 on the island in mid-February 1971, 200 on 20 January 1972, 60 in January 1976, and 50 through winter of 1978-1979. There were substantial gaps in sightings prior to the March birds in Table III, which are therefore taken as migrants. The Bouteilliers reported it regularly (Table IV), and James Bouteillier listed an unusual bird on 24 July 1902, which appears as a male specimen in the Dwight collection.

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I am very grateful to many observers of the birds on Sable Island for supplying notes of their sightings. Christel and Normal Bell, and later Alban A. Richard, as island residents supplied valuable continuity. My former students, Jean Boulva, A.R. Lock, E.H. Miller, Howard Ross, Wayne Stobo, and Daniel Welsh made extensive records during their work on the island. R.G.B. Brown, Donald Gunn, Robert Lamberton, and Bruce Mactavish also made observations and notes available. My colleague Eric Mills supplied extensive and detailed notes from his visits and also read this manuscript critically. Davis W. Finch, during visits with me and others helped to sharpen our field perceptions and enthusiasms. He also discovered the extent of the Dwight collections in the American Museum of Natural History. Earl H. Reed of the Science Museum, Springfield, Mass., sent valuable information on parts of the Dwight collections there. Correspondence with Mr. Robert S. Bouteillier of Saanichton, B.C. gave me many valuable insights into the activities of the ornithological Bouteilliers on Sable Island at the turn of the century.

Over the years, Dr. W.E. Godfrey, and latterly Dr. Henri Ouellet, of the National Museums of Natural Sciences, Ottawa, have received many photographic slides and specimens from the island and have rendered opinions with unfailing good humor and patience. Their final task has been to read this manuscript. I am most grateful for their professional help, but any errors remain mine alone.

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THE FOURTH A.C. NEISH MEMORIAL LECTURE
FOOD, ENERGY, AND THE ENVIRONMENT

David Pimentel*

Introduction

At present the world population is 4.3 billion (10^9) and is projected to reach 6 to 7 billion by the turn of the century (NAS 1977). The population is expected to continue growing and shortly after 2100 reach anywhere from 10 to 16 billion, a level 2 to 4 times the present number (Fig 1). Population numbers of this magnitude can be expected to strain the resources of the world to provide adequate food and other essentials for society. Competition for land and water by agriculture and other sectors of society will be intensified. Demands will increase for fossil energy which is vital to agriculture, public health, industry, and other sectors of human society.

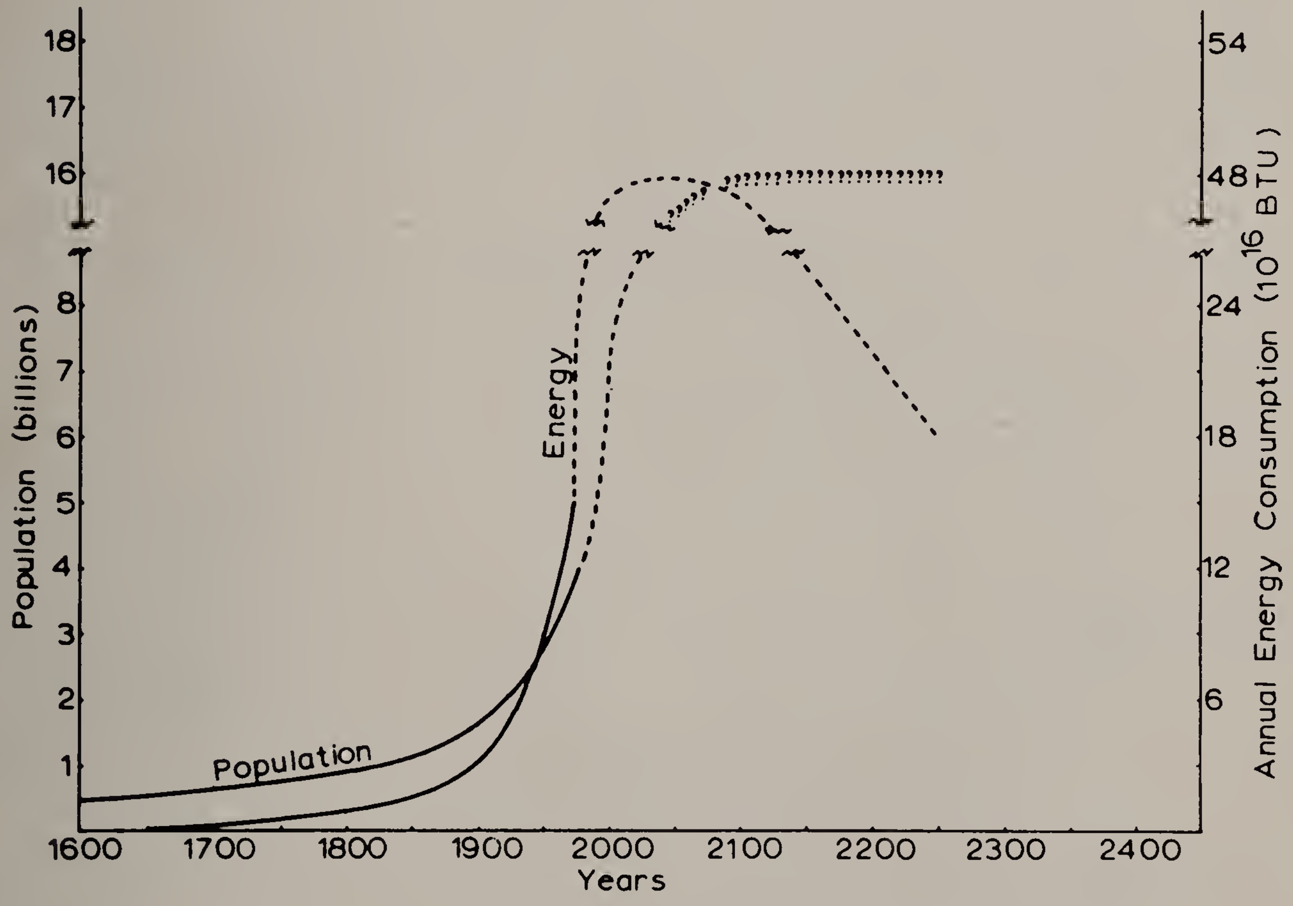

Fig 1. Estimated world population numbers (__________) from 1600 to 1975 and projected numbers (. . . .) (????) to the year 2250. Estimated fossil fuel consumption (__________) from 1650 to 1975 and projected (. . . .) to the year 2250 (after Pimentel et al. 1975).

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Before we can even attempt to find answers to these vast supply/demand problems concerning our vital resources, the interdependencies of food, land, water, and energy and the entire world ecosystem must be understood. This is because each in a way is related to another and each is an integral part of the whole system. Discussions based on only energy or only land needs in the food system are not effective because all are functionally interrelated components of what we call the human ecosystem (Fig 2).

Energy use in the agricultural sector, especially in industrialized nations, is increasing more rapidly than in any other sector of the economy (Leach 1976; Pimentel & Pimentel 1979). In agricultural systems, energy is used to produce fertilizers, pesticides, and farm machinery. Also, large quantities of fuel are used directly in the operation of the farm machinery.

In addition to greater use of fossil energy, increasing crop and livestock yields through intensive management practices are resulting in serious degradation of land and water resources as well as contributing to environmental pollution. Indeed, soil erosion is a serious problem throughout the world and, even now, is responsible for significant reductions in the productivity of this valuable natural resource (Eckholm 1976; Pimentel et al. 1976).

Of concern also is that water resources are being mined extensively in many parts of the world (Dunne & Leopold 1978). In addition, current irrigation practices are causing salinization and waterlogging of some agricultural soils (Eckholm 1976; Pimentel & Pimentel 1979). Both conditions reduce the productivity of the soil. The widespread use of fertilizers and pesticides to increase yields is causing pollution of the natural environment, including vital water resources. Further, in some areas agricultural chemicals have become a serious hazard to public health as well as to valuable fish, birds, and insects (NAS 1977).

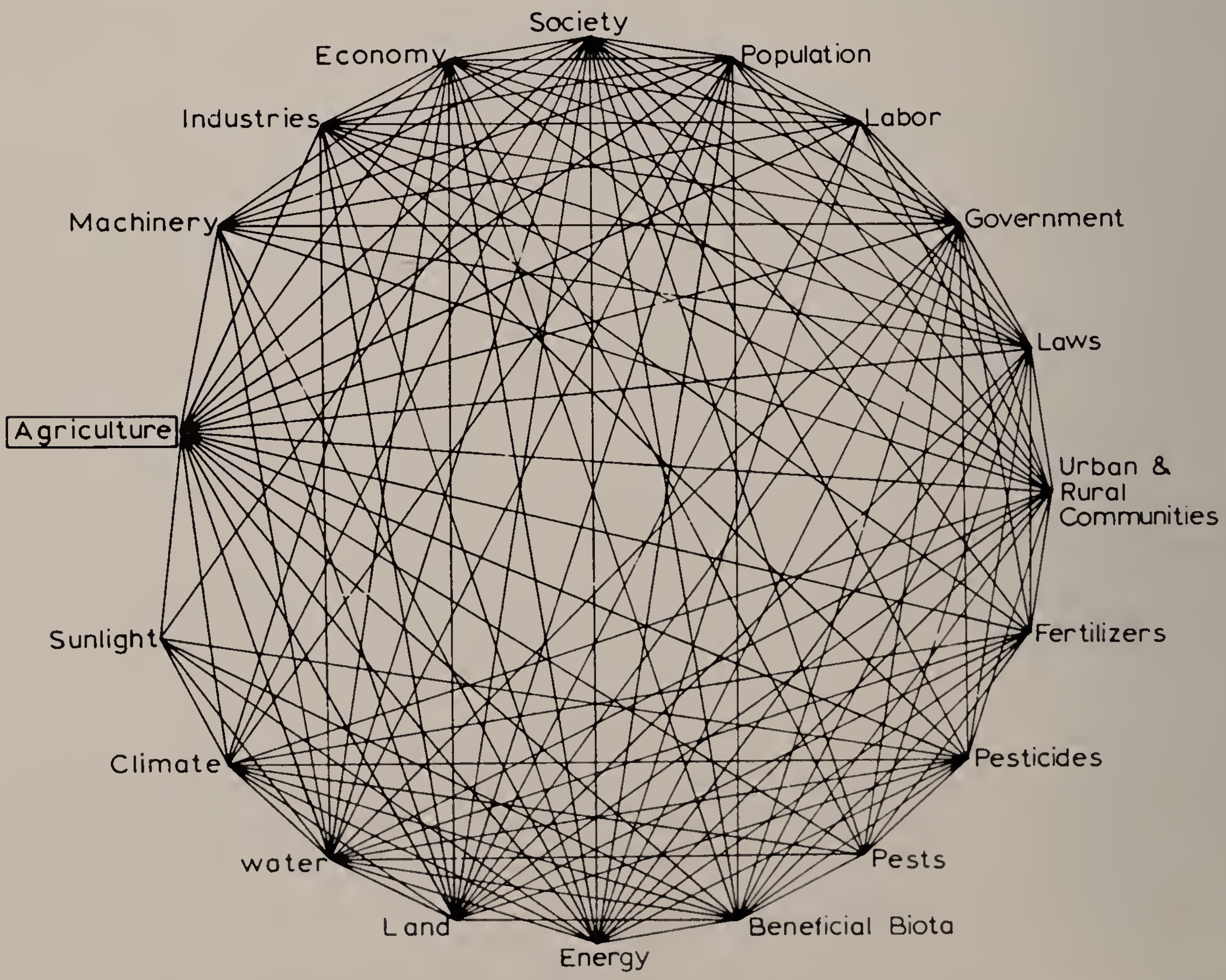

Fig 2. The interdependency of agriculture and the ecological and social system.

Human society can no longer afford to waste energy and degrade land and water resources while producing its food supply. If society expects to meet its future food needs, it must start now to modify present practices, to develop alternatives to present practices, and to develop new strategies of agricultural production that will enable society to meet the critical needs for human food in the coming decades. In this paper, I examine current energy, land, and water resource use in the food systems of industrial societies and then analyze alternative technologies that have the potential for an ecologically sound food system, one with a conservative energy input.

Energy Use in the Agricultural and Food System of North America

Crop and Livestock Production

In industrialized nations, fossil energy has become as vital a resource for crop and livestock production as land and water. Yearly, each North American consumes as food the equivalent of 1500 ℓ of oil. This amount of energy in the form of food represents about 17% of all the fossil energy used in Canada and the United States (Pimentel & Pimentel 1979). The energy inputs for the food system of Europe are similar to North America. The United Kingdom used 16% for their food system while Sweden uses 10 to 20% for only production and distribution (Leach 1976; Olsson 1978). Actual agricultural production uses about 6% of total United States energy and in the United Kingdom about 5% is used (Leach 1976). Food processing, packaging, transport, storage, and home preparation use the remainer.

The major uses of energy in agricultural production are for fuel to run farm machinery and for the production of fertilizers and pesticides (Table 1). Both pesticides and nitrogen fertilizers are produced directly from energy resources.

Table I. Energy inputs per hectare in United States corn production (Pimentel & Pimentel 1979).

Inputs	**Quantity/ha**		**kcal/ha**
Labor	12	hrs	5,580
Machinery	31	kg	558,000
Diesel	112	ℓ	1,278,368
Nitrogen	128	kg	1,881,600
Phosphorus	72	kg	216,000
Potassium	80	kg	128,000
Limestone	100	kg	31,500
Seeds	21	kg	525,000
Irrigation	780,000	kcal	780,000
Insecticides	1	kg	86,910
Herbicides	2	kg	199,820
Drying	426,341	kcal	426,341
Electricity	380,000	kcal	380,000
Transportation	136	kg	34,952
Total			6,532,071
Outputs			
Corn Yield	5,394	kg	19,148,700
kcal output/kcal input			2.93
Protein yield	485	kg	

Table II. Energy inputs and returns for various food and feed crops produced per hectare in the United States (from Pimentel & Pimentel 1979).

Crop	Crop Yield (kg)	Yield in Protein (kg)	Crop Yield in Food Energy (10^6 kcal)	Fossil Energy Input for Production (10^6 kcal)	kcal Food/feed Output/kcal Fossil Energy Input	Labor Input (manhours)
Corn	5,400	485	19.1	6.5	2.9	12
Wheat	2,060	247	6.8	2.8	2.4	7
Oats	1,730	242	6.7	2.2	3.1	6
Rice	6,160	462	22.4	14.4	1.6	17
Sorghum	3,030	344	10.5	5.4	2.0	12
Soybean	1,880	640	7.6	1.8	4.2	10
Beans, dry	1,460	325	5.0	2.7	1.8	10
Peanuts	3,720	320	15.3	10.9	1.4	19
Apples	17,920	36	9.6	18.0	0.5	175
Oranges	19,040	193	6.8	18.3	0.4	173
Potato	34,380	722	19.7	16.0	1.2	35
Spinach	11,200	358	2.9	12.8	0.2	56
Tomato	49,620	496	9.9	16.6	0.6	165
Brussels Sprouts	12,320	604	5.5	8.1	0.7	60
Alfalfa	6,830 (dry)	1,127	15.4	2.5	6.2	13
Tame Hay	5,000 (dry)	200	8.6	1.7	5.0	16
Corn Silage	31,020	393	25.3	6.3	4.0	15

Table III. Energy inputs and returns per hectare for various livestock production systems in the United States (Pimentel 1980).

Livestock	Animal Product Yield (kg)	Yield in Protein (kg)	Protein as kcal (10^3)	Fossil Energy Input for Production (10^6 kcal)	kcal Fossil Energy Input/ kcal Protein Output	Labor Input (manhours)
Broilers	2008	186	744	7.3	9.8	7
Eggs	910	104	416	7.4	17.8	19
Pork	490	35	140	6.0	42.9	11
Sheep (grass-fed)	7	0.2	0.8	0.07	87.5	0.2
Dairy	3270	114	457	5.4	11.8	51
Beef	60	6	24	0.6	25.0	2
Dairy (grass-fed)	3260	114	457	3.3	7.2	50
Beef (grass-fed)	54	5	20	0.5	25.0	2
Catfish	2783	384	1536	52.5	34.2	55

Pesticides are made primarily from petroleum while nitrogen fertilizer is made primarily from natural gas.

Food crops vary as to the amount of energy used in their production. Corn, a fairly typical grain crop, requires about 600 ℓ of gasoline equivalents per hectare. This amounts to an expenditure of about 1 cal of fossil energy for 3 cal of corn produced (Table I). Most grains produced in Canada and the United States yield from 2 to 3 cal of grain per fossil-energy calorie expended (Table II).

Producing other types of food crops, however, is not as energy efficient as grain production. For example, in apple and orange production, about 2 cal of fossil energy are expended per 1 cal of fruit produced (Table II). Culturing vegetables requires from 1 to 5 cal energy input per 1 food calorie produced (Table II).

Although fruits and vegetables require larger energy inputs per food calorie than grain, neither are as energy-expensive as producing animal protein. From 10 to 90 kcal of fossil energy are required to produce 1 kcal of animal protein (Tables II, III). The major reason that animal-protein products are significantly more energy-expensive than plant-protein foods is that forage and grain crops have to be grown, harvested, and then fed to the animals. Also,the forage and feed that maintain the breeding herd are additional energy costs. For example, about 1.3 head of breeding cattle must be maintained to produce 1 calf per year (Pimentel et al. 1975). Of importance is the fact that many of the grains fed to animals are entirely suitable for human consumption. In industrialized nations, about 90% of the grain produced is cycled through livestock to produce milk, eggs, and meat.

Plant-protein production per hectare, especially legume crops like soybeans, contrasts greatly with animal-protein production. For example, about 20 times more protein is produced raising soybeans than producing pork (Tables II, III). Note also that energy inputs for soybean protein are about one-twentieth that for pork-protein production.

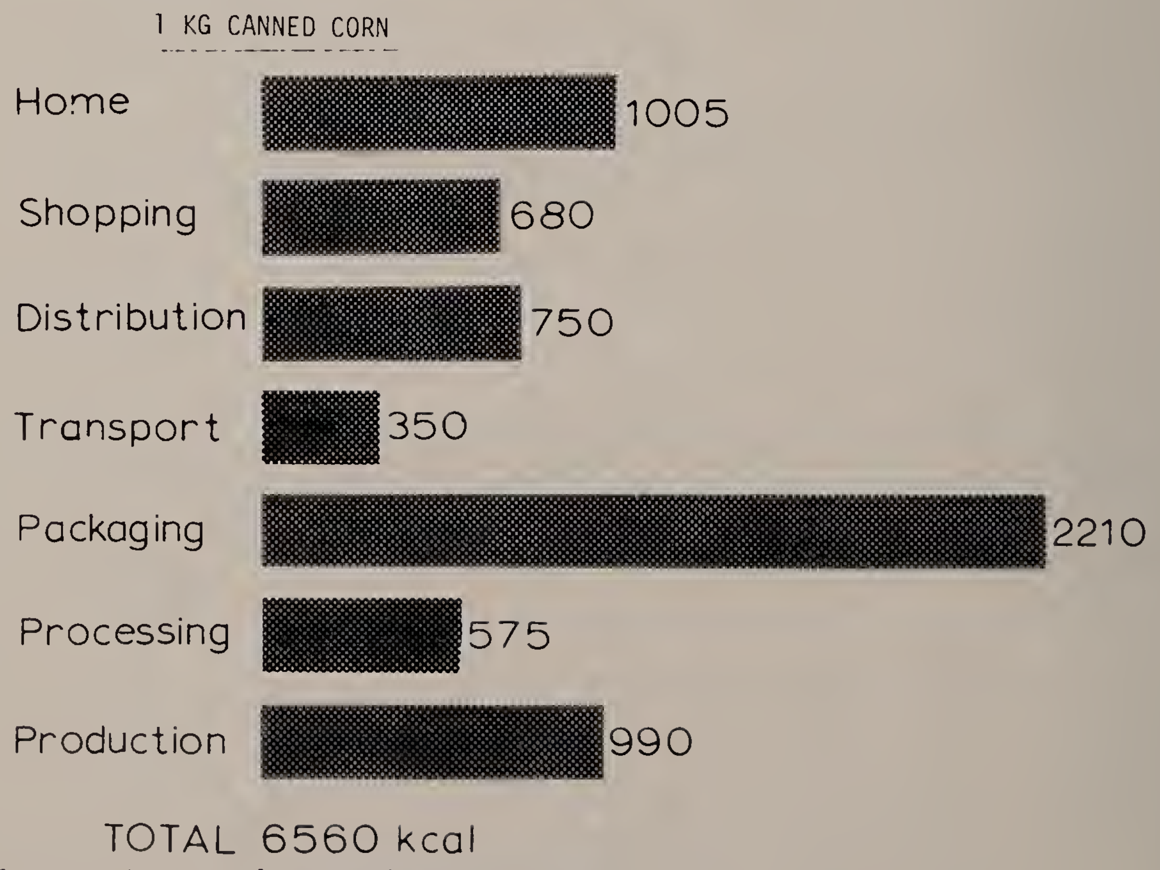

Fig 3. Energy inputs for a 1-kg can of sweet corn. (Note, distribution includes storage and home includes refrigeration, cooking, preparation, and washing. One kg of corn contains 825 kcal of food energy.)

Food Processing and Packaging

Once food is produced it is usually packaged to facilitate wide distribution in the marketplace. In addition, yields of large harvests of perishable foods like fruits and vegetables are frequently processed for use in seasons when fresh crops are unavailable. In the industrialized nations, the fossil-energy inputs are substantial for packaging and also for preserving and processing foods and then placing them in suitable storage (Pimentel & Pimentel 1979). For example, producing sweet corn on the farm uses only about 10% of the total energy used to produce, process, market, and cook 1 kg of canned, sweet corn (Fig 3). Most of the approximately 2785 kcal that are expended in processing are used up to make the steel can. Specifically, the heat-processing and canning of the corn requires only 575 kcal, while the production of the steel can itself requires about 2210 kcal.

Foods are also frozen to preserve them for future use. The fossil-energy inputs for processing by freezing are significantly greater than for processing for canning, averaging 1815 kcal/kg for frozen food compared with only 575 kcal/kg for canned (Figs 3, 4). This is because processing by canning requires only heating and packaging, while freezing may require brief heating (blanching), then cooling, packaging, and freezing at –18° C or lower.

Furthermore, once processed, canned foods are stored at room temperature (actually, slightly cooler is recommended), whereas frozen food must be kept in freezers at temperatures of –18° C or lower. Maintaining such a low temperature requires about 265 kcal/kg per month of storage (USBC 1975). As frozen foods are stored about 6 months, this energy cost must be added to the freezing cost, making the total energy input for frozen food much greater than that for canned food (Figs 3, 4). Fortunately, however, the moisture-resistant plastic and paper con-

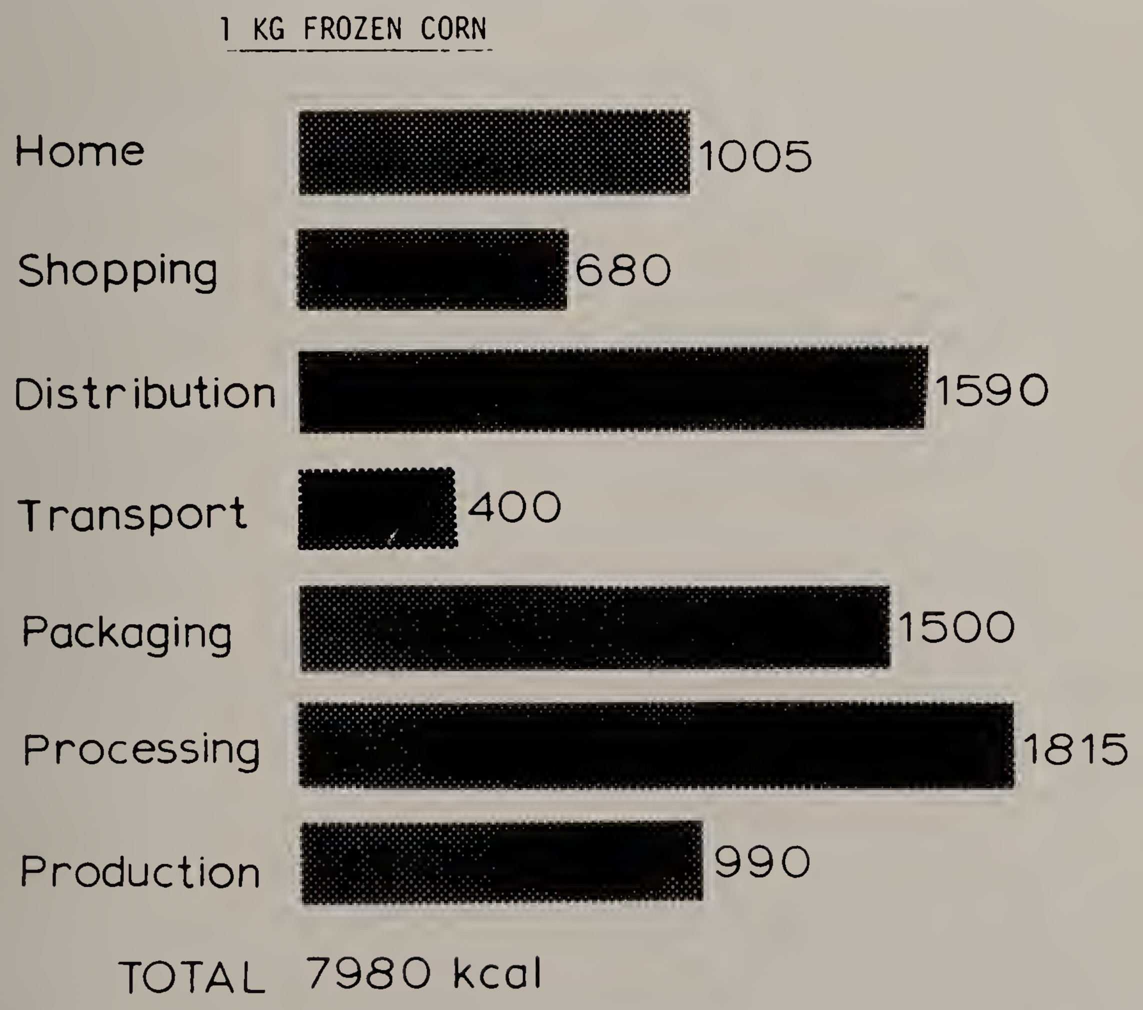

Fig 4. Energy inputs for 1-kg frozen package of sweet corn. (Note, distribution includes storage and home includes refrigeration, cooking, preparation, and washing. One kg of corn contains 825 kcal of food energy.)

tainers for frozen foods require less energy to manufacture than the metal cans or glass jars used for canned food. Another important consideration is that the overall nutritive value and palatability of frozen foods, especially vegetables, are superior to canned foods.

Another way of preserving foods is drying. If done in fossil-fueled ovens, drying is expensive but if done by the sun, the external energy cost is eliminated. In suitable climates, solar drying of food exposed on simple wooden racks is one of the least costly processes for preserving fruits, vegetables, and meats. Salting, another way of processing vegetables and meats for safe storage, was used in the past and is still used today. Salting is also one of the least energy-intensive methods of processing foods requiring only 23 kcal/kg of meat processed (Pimentel & Pimentel 1979). This has some disadvantages, especially related to palatability and ultimate salt content of the rehydrated food. For some individuals the high residual sodium content of foods may be a health problem.

Two of the most energy-intensive methods of processing foods are freeze-drying and smoking. Freeze-drying, which involves both freezing and drying processes, requires about 3540 kcal/kg of food processed. Smoking uses about 4500 kcal from wood per kilogram of food smoked (Casper 1977; Pimentel & Pimentel 1979).

Transport of Food

Movement of food from farm to home is an essential part of the food system. Transport of food products is estimated to be about 60% by truck and about 40% by rail (Pimentel & Pimentel 1979). Based on data for energy requirements of truck and rail transport, the energy required to move 1 kg of food product is calculated to be about 0.5 kcal/km. Assuming 640 km is the average distance that foods are moved, then the energy input per kilogram moved is about 350 kcal.

Although the 350 kcal/kg of food transported is an average figure, frequently much greater energy inputs are required for transporting foods to the marketplace. Consider the journey of a 0.5-kg head of lettuce that has a food energy value of only about 50 kcal. When this lettuce is transported by truck, for example, from California to New York, a distance of 4827 km, the energy expended is about 1800 kcal of fossil energy. This means that just for transport, about 36 kcal of fossil energy are expended per kilocalorie of food energy in the lettuce.

Cooking and Preparing Foods

Foods for human consumption are cooked, heated, and/or cooled and all of these operations require the expenditure of energy. In industrialized nations, an estimated 9000 kcal of fossil energy are used per person per day merely for home refrigeration and cooking of foods by gas or electricity (Leach 1976; Pimentel & Pimentel 1979). About 5000 kcal are required, in addition, for washing and for the paper products used in serving. As the per capita consumption of food is 3500 kcal/day, this is 4 cal of energy expended to prepare and serve each calorie of food consumed.

Cooking over an open wood fire requires even more energy than either gas or electricity. Heating food over an open wood fire is only 8 to 10% efficient in transferring heat to food (Stanford 1977) and constitutes an inefficient and costly use of wood fuel. In contrast, the electric stove is 20% efficient in transferring energy to food when the production of electricity itself is taken into account (Pimentel & Pimentel 1979). Of the 3, gas stoves are the best with an efficiency of 33%. Thus, both the kind of fuel available and equipment used will influence the amount of energy needed to heat process a given amount of food.

Environmental Impacts

In addition to consuming large amounts of fossil energy, the industrialized agricultural production system is causing serious environmental problems. Vast land areas are devoted to crops and pastures and much of this is exposed to agricultural chemicals like pesticides and fertilizers. While these chemicals are helpful in increasing crop yields, they also find their way into the environment and cause problems there.

For example, each year in the United States, pesticides cause a minimum of $1 billion damage to the environment and public health (Pimentel et al. 1979). From the public health standpoint there is concern about the 45,000 Americans who are poisoned each year with pesticides and the 200 of these who die. Other major problems caused by pesticides include: livestock poisonings; increased control expenses resulting from the destruction of natural enemies and pesticide resistance; crop pollination problems and honeybee losses; crop losses; fish and wildlife losses; and various governmental expenditures used to reduce environmental and social costs resulting from widespread pesticide use (Pimentel et al. 1979).

Nitrogen fertilizer, another major agricultural chemical, often leaches from the land into the ground water and contaminates it. As a result, the contamination of drinking water with nitrates and nitrites can be at high enough levels to be hazardous to humans, especially young children (PSAC 1965). Further, the addition of nitrogen to lakes and streams may result in increased eutrophication (PSAC 1965; Beasley 1972). Thus, the heavy use of nitrogen fertilizers and other agricultural chemicals is causing serious environmental problems.

In addition to agricultural chemicals, soils are eroded from agricultural land in Canada and the United States and are washed into streams, reservoirs, and lakes. The soil sediments have many diverse environmental effects. When sediments deposited into the water bodies impede water flow, they may have to be dredged from these bodies. Each year in the United States dredging costs about $500 million (Nelson 1968) plus large energy inputs needed to power the dredging apparatus for removing the soil.

Extensive sedimentation reduces the depth of light penetration into the water and thereby may reduce or limit the growth of plants and the subsequent productivity of the aquatic system. In addition, soil sediments may also have a detrimental effect upon many kinds of fish (Beasley 1972).

The most far-reaching effect is that an estimated 3 billion (10^9) tonnes of soil are washed from United States agricultural lands alone (Pimentel et al. 1976). In fact, agricultural land is the major source of the sediments in Canada and the United States that are washed into aquatic systems.

A recent estimate is that United States agricultural land has lost about a third of its topsoil (NAS 1970). The soil-erosion problem in Canadian agriculture appears to be equally serious. The annual loss of soil from row crops such as corn in the United States is about 45 tonnes/ha (Pimentel et al. 1976). The significant fact is that for each 2.5 cm of soil that is lost from the land, productivity of the land is reduced. In the case of corn with a soil depth of less than 30 cm, each 2.5-cm loss of soil reduces corn yields more than 250 kg/ha (Pimentel et al. 1976). To offset this loss of topsoil and reduced productivity, more fertilizers and other energy-related inputs are needed to maintain yields. Indeed, to compensate for present deterioration, about 47 *l* of gasoline equivalents have to be applied to the crop in the form of fertilizers and other inputs just to maintain current high yields (Pimentel et al. 1976).

The extent of soil erosion is directly related to rapid water runoff from agricultural lands. Water runoff not only carries with it soil, fertilizers, and pesticides, but it also has other far-reaching impacts on agriculture and society. First, the water that runs off the land is no longer available for crop production and thus reduces potential yields for that location (Pimentel et al. 1976). Then, too, rapid water runoff often results in flooding other crops located in lower areas. The estimate is that United States agriculture loses several million dollars in crops annually because of water runoff (USDA 1965). At times, water runoff contributes to serious flooding problems in rural and urban areas in certain regions of the nation.

In addition to all the environmental effects associated with agriculture that have been discussed thus far, other problems exist. Agriculture in the United States consumes more water for irrigation than all other uses of water combined. One study reports that agriculture consumes about 83% of all water withdrawn from streams and lakes in the United States each year, while industry and urban communities consume only 17% (NWC 1973). With this large consumption and increasing demand for water, agriculture will have increasing conflict with other sectors of society for water.

In addition, the clearing of land for crop and livestock production has a detrimental effect on the natural biota. This is because the number and kinds of species that survive in an agricultural system are much fewer than those associated with the natural vegetation.

Lifestyles and Dietary Regimes

Diets in Canada and the United States are typically high-calorie and high-protein. In the United States, for instance, daily per capita food energy consumed is about 3500 kcal (USDA 1980). The Recommended Daily Allowance is about 2350 kcal or 2700 for males and 2000 for females (NAS 1979). The 3500-kcal intake is 1 factor contributing to obesity, a major health problem in the United States (U.S. Senate 1977).

Not only are the diets typical of Canada and the United States high in calories but they are also high in protein, especially animal protein. In the United States about 70 g of animal protein are consumed per capita per day and in addition, about 32 g of plant protein are eaten. The total daily intake is high, 102 g (USDA 1977). Contrast this with the FAO recommendation that 41 g per day is an adequate level of protein intake (FAO 1973). The average total-protein consumption in the United States and Europe is more than twice this recommendation.

To supply the large quantity of animal protein that is consumed in the United States, over 3 billion livestock are maintained; these animals outweigh the United States human population more than 4-fold (Pimentel et al. 1975). In addition to the large amount of forage that is fed the livestock population, they annually consume 60 to 90% of the total grain used in industrialized nations (UKMAFF 1976; USDA 1977). Although forage is unsuitable for human consumption, the grains are excellent foods for humans.

Providing feed for these animals requires land. In fact, in Canada and the United States several million hectares of land are used merely to grow forage and grains for livestock. At present in the United States about 130 million tonnes of grain, an equivalent of 605 kg grain per person, are fed animals to provide meat and other animal products for the high animal-protein diets consumed.

The total fossil energy expended to maintain the United States livestock population is 413 x 10^{12} kcal and includes the cost of maintaining land needed for pasture and grain production and the husbandry of the livestock (Pimentel et al. 1980a). This is in sharp contrast with all other crops produced in the United States, for which an average of 700 x 10^{12} kcal of energy are expended; this represents a significant quantity of energy only for production. When energy costs of processing, transport, and preparation and cooking are included, the total increases to about 3.3 x 10^{15} kcal/yr. This is indeed high and amounts to about 17% of the total energy economy of the United States and, as mentioned, is similar for Canada. A change in eating patterns to consume less meat and other animal products in industrialized nations might improve human health and certainly would significantly reduce the land and energy inputs required in the food system.

With this in mind it is interesting to consider what would happen if the United States moved from a grain/grass-fed livestock system to only a grass-fed system. Analyses show that the total amount of animal protein that could be produced would be reduced by nearly one-half (Pimentel et al. 1980a). As a result, daily per capita protein consumption in the United States under this system would be reduced from 102 g to about 70 g/day (Pimentel et al. 1980a). Even so, the 70 g/day is still significantly higher than the 41-g level recommended by FAO.

A change to a grass-fed livestock system would release 130 million tonnes of grain for direct human consumption and reduce energy input in production by 60% (Pimentel et al. 1980a). This amount of grain could feed about 400 million humans or nearly twice the current population of the United States or 17 times the population of Canada.

Indeed, cycling plant protein through animals is costly in both land and energy, and is an inefficient way to produce protein. In all probability, such a drastic change in production patterns will not be necessary, but if land and energy resources become scarce in the United States and Europe some modification of present protein production will need to be considered.

A comparison of the energy requirements to produce a high plant-protein diet versus a high animal-protein diet provides helpful insight into some of the differences. High plant-protein diets or vegetarian diets are usually of 2 major types: the lacto-ovo diet that includes eggs, milk, and milk products and the complete vegetarian diet that includes only plant proteins.

The following example illustrates some of the differences these dietary regimes have in fossil fuel requirements for production. For these calculations the average daily calorie food intake of 3300 kcal is held constant for the 3 diets. The amount of protein is over 100 g/day in the high animal protein or nonvegetarian diet and is about 80 g in the all-vegetarian diet.

Nearly twice as much fossil energy is expended for food production in a lacto-ovo vegetarian diet than is expended for the complete vegetarian (Fig 5). For the nonvegetarian diet, the fossil energy input is more than 3-fold that of the complete vegetarian diet.

Based on these sample calculations, the complete vegetarian diet is more economical in terms of fossil energy than either of the other 2 types of diets. Energy expenditure is not the only factor to be considered when dietary choices are made. Personal choices are often based on social and cultural attitudes as well as desirable palatability characteristics. Another major consideration is that there can be significant nutritional differences between the pure vegetarian diet and diets that include animal products. This is because vitamin B_{12}, an essential nutrient, is lacking in pure vegetarian diets and must be taken as a dietary supplement. Further, the quality of protein consumed may not be adequate because that depends on the combination of plant proteins consumed. When the essential amino acids of plant foods are complemented, then protein quality of a vegetarian diet will be satisfactory. A diet of all plant foods is usually of greater volume and bulk, making it difficult for young children and women to consume

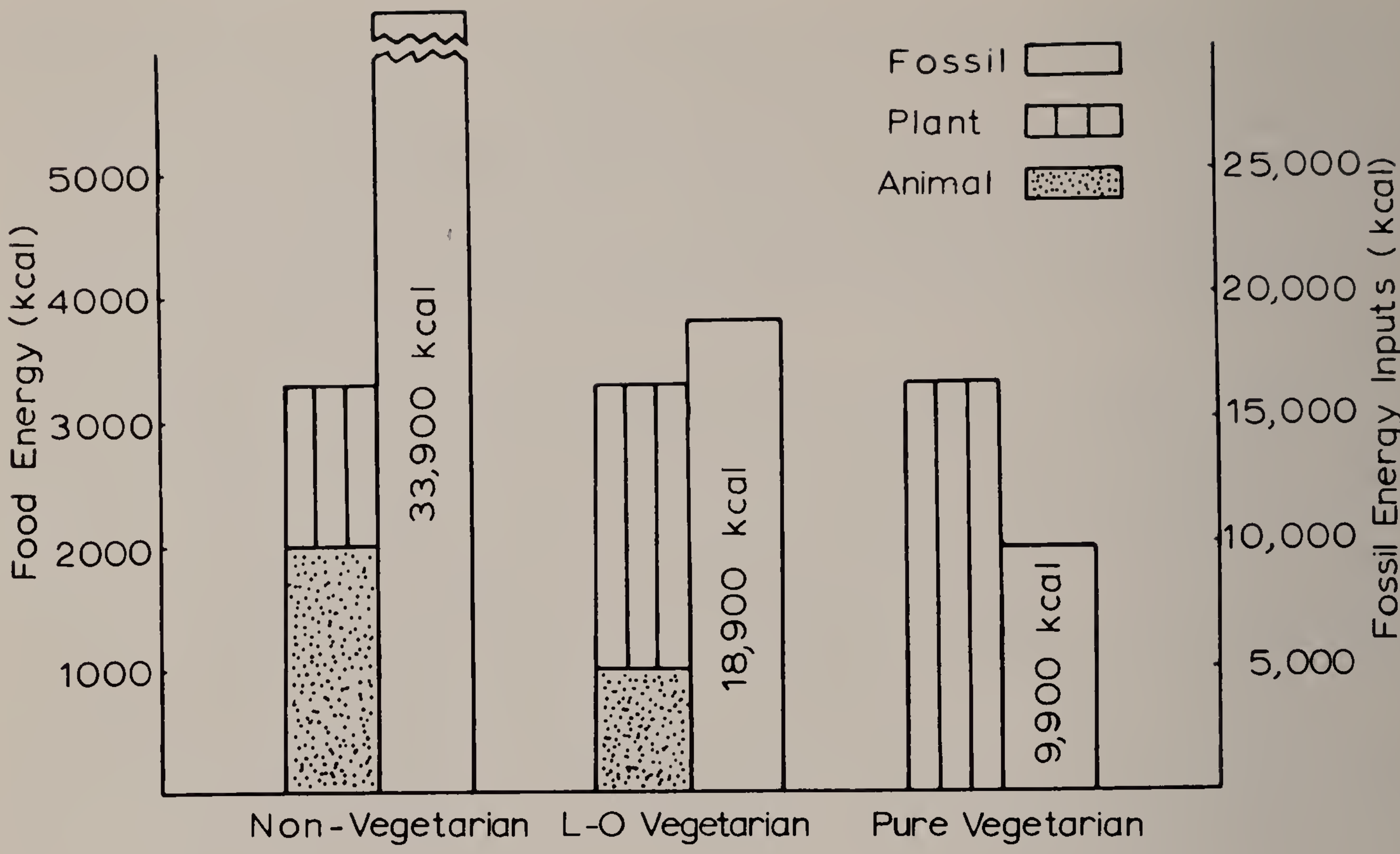

Fig 5. Daily food energy intake of pure vegetarians, l-o (lacto-ovo) vegetarians, and nonvegetarians and the calculated fossil energy inputs to produce these diets under United States conditions.

the quantities necessary to meet all nutritional needs. In addition, infants, rapidly growing adolescents, pregnant and lactating women, and other nutritionally vulnerable groups consuming pure vegetarian diets may need nutritional supplements of vitamins A and D and iodine.

Although these examples are based on limited data, they suggest that significant reductions in energy use as well as land and water resource use are possible by modifying diets and eating patterns. Further reductions in quantity of energy and other resources are possible by reducing the total caloric intake of the population from 3500 kcal to something less than 2500 kcal. Note that optimum calorie intake for an individual is based on his or her basal metabolic rate, physical activity, and the effect of food consumed (Guthrie 1979).

How much fossil energy could be saved in the food systems of industrialized nations like Canada and the United States and have an ecologically and energetically sustainable system? My estimate is that as much as 50% could be saved, while maintaining high crop yields and improved environmental quality.

Biomass as an Energy Source

In considering all possible energy resources, conversion of biomass energy often has been suggested as a substantial energy source. Today energy from biomass conversion amounts to less than 1% of the United States energy supply, whereas in 1850 about 91% of the energy supply came from biomass in the form of fuel wood (EOP 1977). Of course, in 1850 the United States population was only about 23 million or about one-tenth the current level of 215 million, and per capita energy consumption was about one-fifth current consumption. Today, wood supplies a mere 1% of United States and 4% of Canadian energy needs (USBC 1977; CYB 1977). In certain regions wood is an important fuel resource.

The United States in 1979 consumed more than 19 x 10^{15} kcal. This is more than the total sunlight energy fixed by photosynthesis in the United States, about 13.5 x 10^{15} kcal (Fig 6).

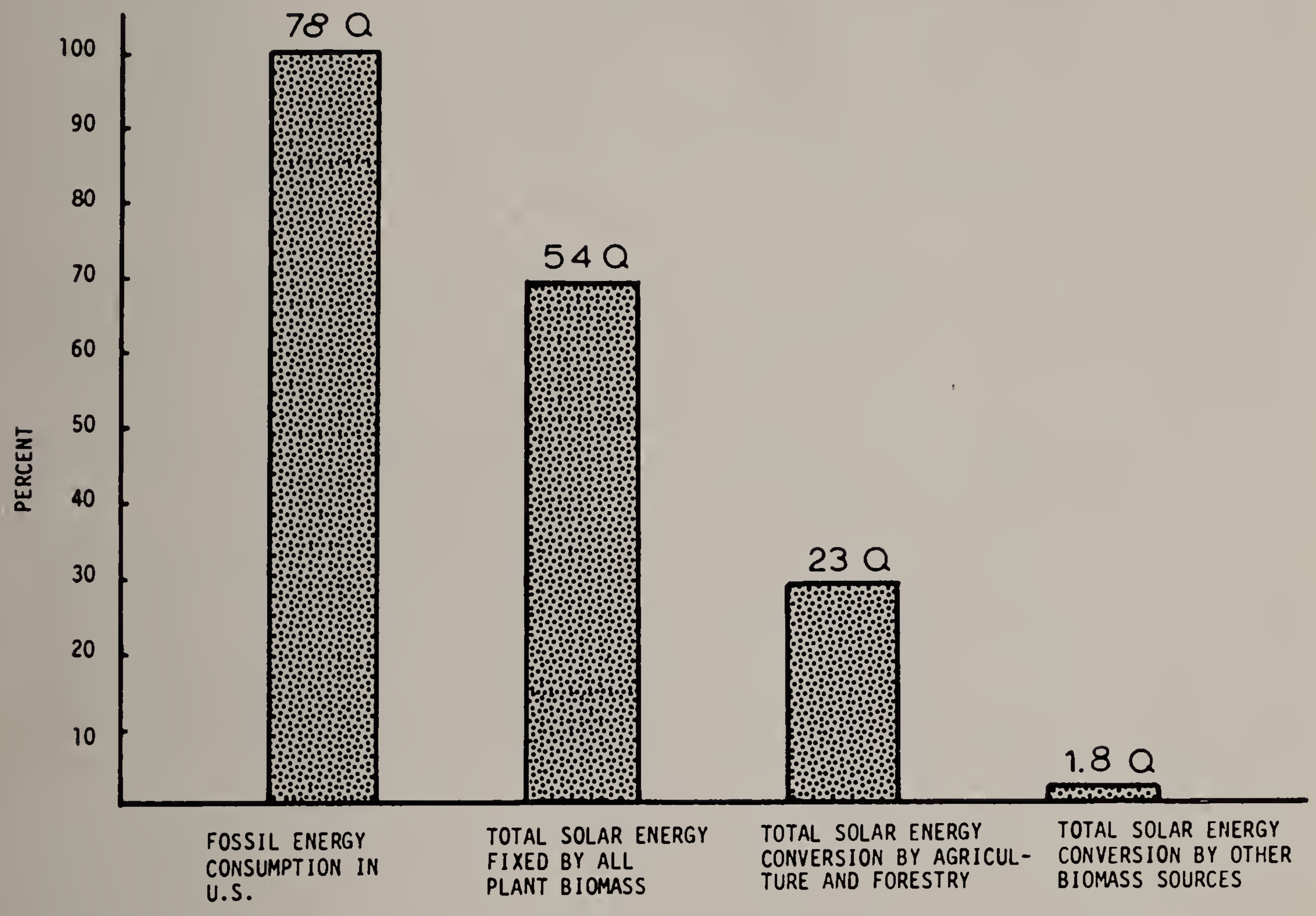

Fig 6. Biological solar energy conversion compared with fossil energy consumption in the United States; all data calculated for 1 yr.

About half of the total solar energy fixed is harvested in the form of agricultural and forestry products. This has several significant implications. First, about half of all the solar energy fixed by plants in the United States already is being harvested in the form of food, fiber, and forest. Thus, this energy source is a vital factor in the United States economy. Further, the value of solar-energy conversion in agricultural and forestry production must be fully recognized, and efforts to utilize the remaining biomass directly for energy conversion must not reduce the effectiveness of agriculture and forestry. This also applies to Canada.

A wide range of proposals exists for the utilization of crop remains for conversion of biomass energy (Alich & Inman 1974; Alich et al. 1976). An analysis of the agricultural, environmental, and energetic aspects of the use of crop remains suggests that little or none of these remains should be used for biomass-energy conversion (Pimentel et al. 1978). In fact, the evidence suggests that crop remains left on the land function to prevent sediment runoff, to conserve soil and water, to maintain soil organic matter and soil structure, and to prevent nutrient (N, P, K, Ca, etc.) loss. Energetically the removal of most crop remains will cost Canada and the United States more in terms of energy in the long run than any short-term gains that are currently possible (Pimentel et al. 1980b). The environmental impact of utilizing forest residues is less than using crop residues but there are still problems in utilizing forest residues (Pimentel et al. 1980b).

Converting forest residues into various fuel sources will deplete nutrients at forest sites and increase soil erosion. Careful forest management practices can reduce the impact on forests if forest residues are utilized.

Canada and the United States are using some grain for producing gasohol (DOE 1980; OTA 1980). If oil or natural gas are employed in the fermentation/distillation process of making ethanol, then the inputs of high-grade energy are 114,000 BTU to produce 1 gal (Ca. 3.79 *l*) of high-grade ethanol with an energy value of 76,000 BTU (DOE 1980). The net energy loss is 38,000 BTU/gal produced. This net loss can be reduced by more than half if credit is given for the by-product animal feed (11,000 BTU) and refinery credit (8,000 BTU). However, there is still a net loss.

If the fermentation/distillation plants are fired with coal, then a process of converting low-grade fuel (coal) into high-grade fuel (ethanol) has advantages. By this process then, for every gallon of low-grade fuel invested, about 2 gal of high-grade fuel are obtained (DOE 1980). The cost of a net gallon (3.79 *l* of ethanol was calculated to be $2.14, which is expensive compared with current gasoline prices. Ethanol is made competitive with gasoline by federal and state subsidies that may run as high as $1.13/gal.

The subsidies are paid by the public (taxes). The public pays a second time in higher meat, milk, and egg prices. As mentioned earlier, 90% of United States grain is fed to livestock. Livestock are fed surplus grain, the same surplus grain that gasohol producers are drawing on (DOE 1980). Increased demand for this surplus grain will raise the price of grains. Clearly, high-priced grain will result in higher prices paid for meat, milk, and eggs.

Biomass resources, including grains, should be utilized to help supply fuel needs of Canada and the United States. Although the contribution from biomass may be only 5 to 10% of these nations' needs, every resource should be carefully used. Utilizing biomass as an energy source has numerous environmental, economic, and social costs associated, hence, great care must be exercised in making use of our valuable biomass resources.

Conclusion

Sufficient food is being produced in the world today to feed its population adequately if it were effectively distributed. With the resources of land, water, and energy already in short supply in many parts of the world, it may not be possible to feed the world population adequately in the future.

No longer can we afford to make ad hoc decisions affecting isolated sections of the world or even segments of society within a nation. The scope of the problems facing us now is all-encompassing. They require first an understanding of the interdependencies of food production, and supplies of arable land, water, and energy. Decisions about 1 facet will affect the status of another. This means decisions are more difficult to make and require a depth of understanding about the carrying capacity of the earth's resources. We all have a stake in how these vital decisions are to be made for they will affect the quality of our life and even the survival of our progeny.

Research is needed on: (a) how to integrate both crop and livestock production with other components of the ecosystem to reduce energy inputs while becoming more ecologically sound; (b) the nutritional needs of humans as a basis for decisions concerning which crop and livestock systems can best meet these needs with minimum energy inputs while maintaining a sustainable agricultural environment; (c) how to produce agricultural products as close to the consumers as practical to minimize the expenditure of transport energy; (d) developing food processing and packaging systems that are energy efficient; and (e) devising ways and means of conserving energy in home cooking and preparation.

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BIOLOGY OF PRUNUS PENSYLVANICA L.F.

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Prunus pensylvanica L.f. pin-cherry (Rosaceae) is a component of newly cleared or burnt forest land. Its rapid establishment results from wide dispersal by birds who eat the flesh of the fruit and regurgitate the bony seeds.

Following a period of dormancy and cold temperature, the seeds germinate readily. In some of the most favorable locations in Canada, the seedlings grow to a height of 10 m or more. The leaves of this species are poisonous to livestock under certain conditions. It is a beneficial nurse crop of coniferous seedlings and is sometimes cut for firewood.

Prunus pensylvanica L.f., la cerise d'été (Rosacées), se retrouve sur les sites de forêts récemment abattues ou incendiées. Il s'établit rapidement grâce à la grande dispersion de ses graines effectuée par les oiseaux qui consomment la chair de ses fruits et régurgitent les graines.

Après une période de dormance et de températures froides, les graines germent facilement. Dans quelques unes des régions du Canada qui leur sont les plus propices, les jeunes pousses croissent pour atteindre jusqu'à 10 m ou plus. Dans certaines conditions, les feuilles de cette espèce sont toxiques pour le bétail. La cerise d'été est aussi utile pour la protection des jeunes pousses de conifères et on s'en sert parfois comme bois de chauffage.

1. Name

Prunus pensylvanica L.f. — pin-cherry, bird-cherry, fire-cherry; cerises d'été. Rosaceae, rose family, Rosacées.

2. Description and Account of Variation

A deciduous tree up to 15 m in height, in older specimens the original leader has generally been killed and the trunk severely curved; bark reddish-brown with broad yellowish lenticels; shoots narrow with leaves spirally arranged on curved pedicels producing a broad, flat spray of foliage; leaves simple with 2 glands at the base of the blade, margin with irregular serration, veins strongly branched near margin, lanceolate-ovate, apex acuminate, base oblique; flowers (Fig 1a) in umbels or corymbs (Fernald 1950), sepals 5 green, petals 5 white, stamens numerous, pistil 1; fruit a drupe about 3 mm in diameter (Fig 1b), red, containing a simple seed enclosed in a stony endocarp (Lawrence 1951). Sax (1931) and Löve and Löve (1966) report a chromosome number of 2n = 16 while Bolkhovskikh et al. (1969) list a 2n = 32 count. This species is readily distinguished from *P. serotina* Ehrh. which has a row of hairs along the midvein of the lower leaf surface. The fruits of *P. pensylvanica* are glabrous and in corymbs while in *P. persica* (L.) Batsch the fruits are pubescent and usually solitary (Muenscher 1950).

3. Economic Importance

(a) *Detrimental* - Seedlings of *P. pensylvanica* become readily established in old fields and in fields of new plantings of small fruits (Fig 1c).

The leaves of several species of *Prunus,* including *P. pensylvanica,* are poisonous to livestock; in this species, however, the toxicity is lower than in most others (Kingsbury 1964). The cause of poisoning results from the breakdown of a glucoside, amygdalin, in the presence of specific enzymes to form hydrocyanic acid. Muenscher (1949) considered this species as one of the 10 most important in the United States producing hydrocyanic poisoning.

Fig 1. A. Flowers of *Prunus pensylvanica* showing 5 petals, several stamens and a single pistil per flower (1.5x). B. Clusters of fruit (1x). C. Young seedling tree (0.1x). D. Cross-section of root (60x).

(b) *Beneficial* - This species is a source of firewood and an important nursecrop to several species of conifers (Can. Dept. Mines Resour. 1949; Hosie 1969). The fruit is eaten by wildlife (Daubenmire 1947) and is a source of human food (U.S. Dept. Agr. For. Ser. 1948).

(c) *Legislation* - *Prunus pensylvanica* is not covered by any regulatory legislation.

4. Geographical Distribution

In Canada, this species extends from eastern Newfoundland to central British Columbia. It extends northward to about 63° latitude in the Mackenzie District. In the United States, it extends southward to Virginia and westward to Colorado (Fernald 1950). A map showing its distribution in eastern Canada based on records from 1923 to 1939 has been published by Groh and Senn (1940). Figure 2 shows the distribution in Canada as known today.

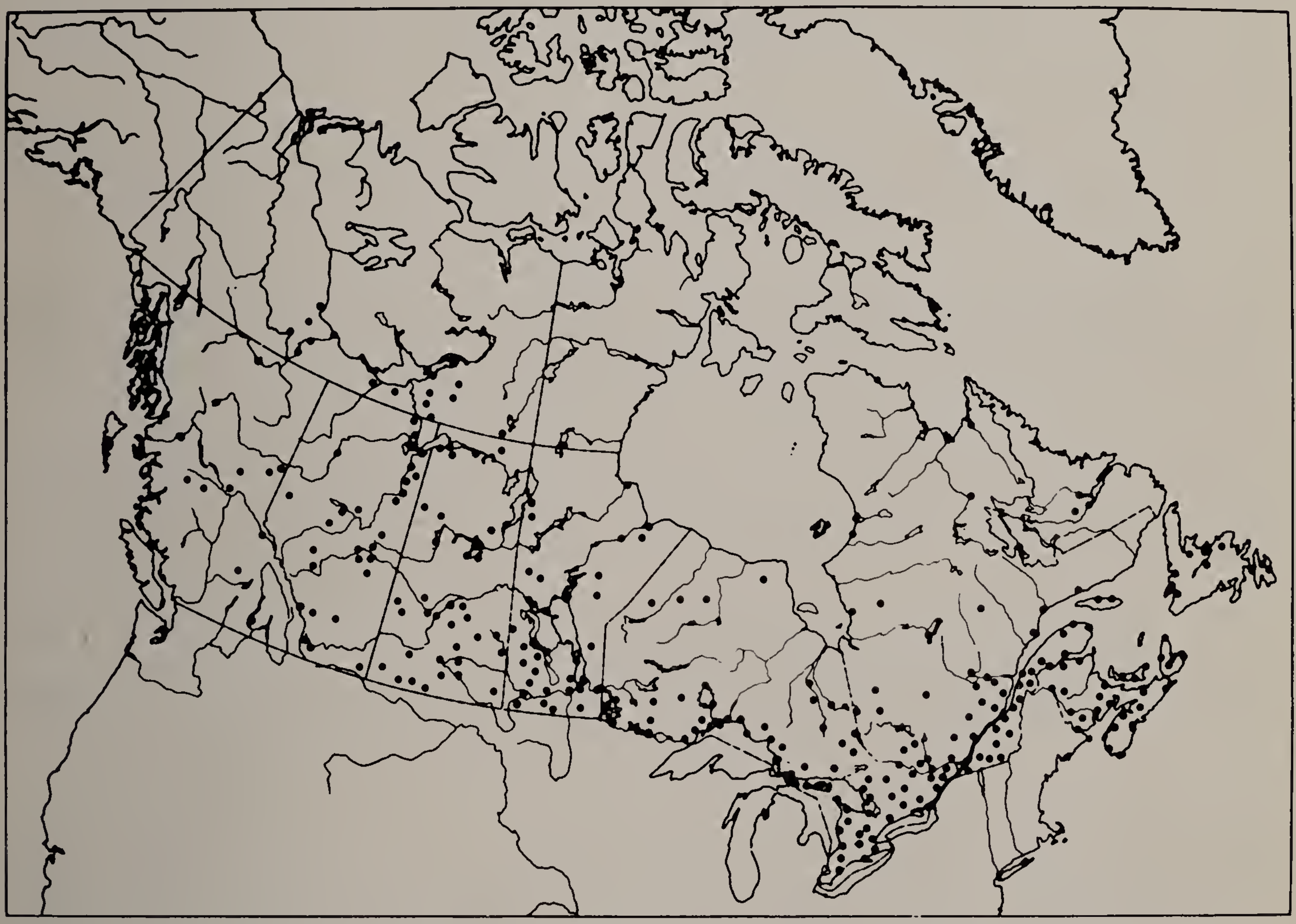

Fig 2. Canadian distribution of *Prunus penslyvanica* from specimens in the herbaria of Agriculture Canada, Ottawa, and the National Museum of Natural Sciences, Ottawa.

5. Habitat

(a) *Climatic requirements* - By comparing maps of climatic factors and the distribution of *P. pensylvanica* it is possible to gain some ideas on factors limiting growth. According to data on permafrost (Dept. Energy, Mines, Resour. 1973) the northern distribution of this species ends at the southern limit of widespread permafrost. In the northern limit on the Prairies, the average annual precipitation is 50.8 cm; the average daily maximum temperature for February is -20°C and the average daily minimum temperature is -30°C. The number of days with an average temperature over 5.6°C is 140, but the frost-free period in some areas is 60 days or less.

(b) *Substratum* - By far the most common soil type in its distribution is the humo-ferric podzol. Less commonly it is found in areas of dominantly organic fibrisol and cryic fibrisol and the luvisolic, gray luvisol (Clayton et al. 1977). The cation exchange capacity of these soils is low and the pH is strongly to quite acidic in reaction.

(c) *Communities in which the species occurs* - In northern Saskatchewan and Manitoba, *P. pensylvanica* grows in association with *Amelanchier alnifolia* Nutt., *Corylus cornuta* Marsh., and *Prunus virginiana* L. and this shrub cover indicates a forest of *Pinus banksiana* Lamb., *Picea glauca* (Moench) Voss, *Betula papyrifera* Marsh., and *Populus tremuloides* Michx. (Rowe 1956). In the Great Lakes region, Maycock and Curtis (1960) record its presence as 55% in the dry, 60% in the dry moist, 38% in the moist and 26% in the wet moist forest, but they give no value for importance. In Levis Co., P.Q., Doyon (1975) reports its occurrence as being considerable in stands of *Populus grandidentata* Michx. Farther up the St. Lawrence, in the county of Rivière-du-Loup, Blouin and Grandtner (1971) found it an understory species in the vegetation series of *Acer saccharum* Marsh. - *Betula lutea* Michx. f.

6. History

Prunus pensylvanica is a species native to Canada and its presence is recorded by Macoun (1883).

7. Growth and Development

(a) *Morphology* - Once the seedling (Fig 1c) has attained a height of 1 m or more, the strong root system begins to grow rapidly in a lateral direction (Hall & Mack 1959). New shoots grow directly from the root system (Fig 1d).

(b) *Perennation* - Scoggan (1950) considered this species to be a microphanerophyte under Gaspé conditions where it grew from 2 to 8 m in height. Under Nova Scotian conditions and in many other areas it grows much taller.

(c) *Physiological data* - The following levels of nutrients (as % dry weight for macro- and ppm oven-dry for micronutrients) were found in a sample of leaves collected at Kentville, N.S. on 24 June, 1980: N, 3.24; P, 0.24; K, 1.27; Ca, 1.34; and Mg, 0.33; micronutrients were: Fe, 195; Mn, 91; Cu, 8; Zn, 22; and B, 35.

(d) *Phenology* - As *P. pensylvanica* occurs throughout Canada, flowering date varies considerably.

The earliest flowering date we found among specimens examined was 3 May 1933 and this occurred at Saskatoon, Sask. The latest flowering specimen was 1 collected on 2 July 1959 from Mackenzie District, N.W.T. A general date of flowering in eastern Canada was the period May 25 to 29.

The earliest record of mature fruit was noted on a specimen collected on 16 July 1941 in Pontiac Co., P.Q. A general period of fruit maturity occurred across southern Canada during the middle of August.

Flower buds of *Prunus* are laid down in August or September of the preceding year (Airy Shaw 1973).

(e) *Mycorrhiza* - None reported.

8. Reproduction

(a) *Floral biology* - Observations on insect pollinations have been made in the field in New Brunswick, particularly about the areas near Fredericton, Stanley, Blissfield, and Tower Hill. In 1980 a good fruit set occurred (3 to 4 fruit per in-

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NOVA SCOTIAN AMANITAS. I.

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In this first paper in a series, 5 taxa of *Amanita* Pers. ex. Hook. occurring in Nova Scotia are considered. *A. flavorubens* Berk. & Mont. var. *gracilis* is described as a new variety, and *A. wellsii* (Murr.) Sacc. is reported for the first time from the province.

Dans ce premier d'une série d'articles, on considère 5 taxons d'*Amanita* Pers. ex Hook. rencontrées en Nouvelle-Écosse. On décrit une nouvelle variété, *A. flavorubens* Berk. & Mont. var. *gracilis,* et on signale pour la première fois la présence dans la province d'*A. wellsii* (Murr.) Sacc.

Introduction

This is our first paper in a series on the amanitas occurring in Nova Scotia. The genus *Amanita* Pers. ex Hook. contains some of the most beautiful, edible, poisonous, and conspicuous mushrooms in the province.

Somers (1881; 1890) compiled 6 lists of Nova Scotian fungi between 1880 and 1890 where he reported 6 species of *Amanita*. Additional reports by Mackay (1908; 1913) and Wehmeyer (1950) increased to 22 the number of species collected in the province. Stewart and Grund (1974) described 2 new species and recognized 25 species and 7 varieties.

In this first paper we consider 5 taxa, of which *A. wellsii* (Murr.) Sacc. and *A. flavorubens* Berkley & Montagne var. *gracilis* var. nov. are reported for the first time from the province. Species complexes and other new taxa will be treated in future papers.

Color references are taken from 3 sources, namely: *Reinhold Color Atlas* (Kornerup & Wanscher 1962), designated thus, 6A7 - light brown, etc.; *Color Standards and Color Nomenclature* (Ridgway 1912), designated thus, "Vinaceous-Buff", etc.; and the National Bureau of Standards color charts (Kelly & Judd 1976), designated thus, ISCC-67 - vivid reddish, etc. Color terms taken from the 3 abovementioned references are enclosed in parentheses; all other color terms mentioned are ours.

Several macrochemical reactions are useful tests on certain taxa of agarics and boleti. Singer (1962, p 77) presents a general history of these tests. Grund and Harrison (1976, p 16) list the chemical reagents and their formulation. An asterisk after a collection number indicates that all camera lucida drawings were based on that collection. All scale markers for microscopic structures are 10 μm. Collections are deposited in the E.C. Smith Herbarium (ACAD), located at Acadia University. Symbols used in the figures are as follows: A = annular terminal cells; C = pseudocystidia or marginal cells at the edge of the lamellae; V = cells of the volva, B = basidioles and basidia; S = spores.

Amanita umbonata Pomerleau

Flore def. Champignon au Québec, pp. 516-518. 1980.

Amanita caesarea (Fr.) Schw. var. *americana* Gilbert in Bres. Icon. Myc. 27: 235. 1941.

Figure 1

Basidiocarp: Pileus 8.0-13 cm broad; shape irregularly conic when young, expanding to subplane, center umbonate, umbo usually low, broadly round, and prominent; margins broadly rounded, sometimes uplifting in old age, striate; surface glabrous; color scarlet red (9B8 - lobster red) immediately upon emergence from universal veil fading to reddish orange (7A8 - reddish orange; ISCC-34 - vivid reddish orange) when young, at maturity fading to yellow (4A7 - sunflower yellow; ISCC-67 - brilliant orange yellow) with a reddish orange umbo (7A8), at maturity and in old age the margins sometimes fading to nearly white; context soft, pallid to pale yellow, thin at margins; odor not distinctive, taste pleasant to lacking. Chemicals on section of pileus: formaldehyde - color of cutis oozes out; guaiac - slowly greenish on edges of lamellae; $FeSO_4$ - cutis brownish; guaicol - context slowly pink; aniline - orange color oozes from cutis; phenol aniline - cutis blackens slowly; 14% NH_4 - oozes yellowish color from cutis; KOH - bleaches cutis to yellow; phenol - cutis purple extending into context. Chemicals on pileal surface: conc. NH_4OH - cutis yellow; KOH - pale yellow. Lamellae free, close, tapering slowly from margin to apex of stipe; yellow (3A3 - pale yellow; ISCC-89 pale yellow). Stipe 11-15 cm long, 0.8-1.3 cm thick, expanding to subbulbous basally; surface glabrous, subviscid, fibrils raising when handled; finely tomentose above annulus; color pale orange apically (5A4 - light orange; ISCC-70 - light orange yellow) becoming pale orange or pale yellowish, (ISCC-89 - pale yellow) at base; annulus membranous, pendant, superior, orange (5A7 - chrome yellow; ISCC-66 - vivid orange yellow) fading to yellow (4A4 - pale yellow, ISCC-89 - pale yellow); volva thick, soft, pliable, membranous, white, sheathing lower quarter to third of stipe; context of stipe pale yellow, stuffed when young, hollowing at maturity.

Spores 8-10 x (6)7-9 μm, white, smooth, ellipsoid, ovoid, to subglobose, nonamyloid, apiculus prominent. Basidia 30-37 x 9-10 μm, clavate, thin-walled, 2- or 4-spored, hyaline in water. Pseudocystidia on edges of lamellae 25-40 x 14-22 μm, clavate or subbulbous, thin-walled, hyaline in water (possibly of annular origin, Bas 1969, p 322). Pileipellis consisting of a layer of gelatinous interwoven hyphae, about 350 μm thick. Pileal context consisting of interwoven thin-walled hyphae 5-15 (20) μm broad. Lamellar trama composed of a bilateral mediostratum consisting of thin-walled hyphae 15-25 μm broad, and a subhymenium of oval, globose, or ellipsoid cells 8-10 μm in diameter. Context of stipe covered by a caulopellis of tightly interwoven hyphae 5-8 μm thick, and the center stuffed with thin-walled hyphae 20-30 μm thick. Annulus of loosely interwoven hyphae with clavate to subclavate terminal cells 20-70 x 12-18 μm, many identical with those found on the lamellar edges. Volva consisting of interwoven hyphae 5-7 μm thick, interspersed with large, collapsed, thin-walled cells.

Habit and Habitat: Gregarious under deciduous trees (poplar, oak, with understory of honeysuckle).

Material Examined: ACAD 13035*, Agriculture Centre, Kentville, Kings Co., Harrison, 31 July 1979; ACAD 11562, Agriculture Centre, Kentville, Harrison, 21

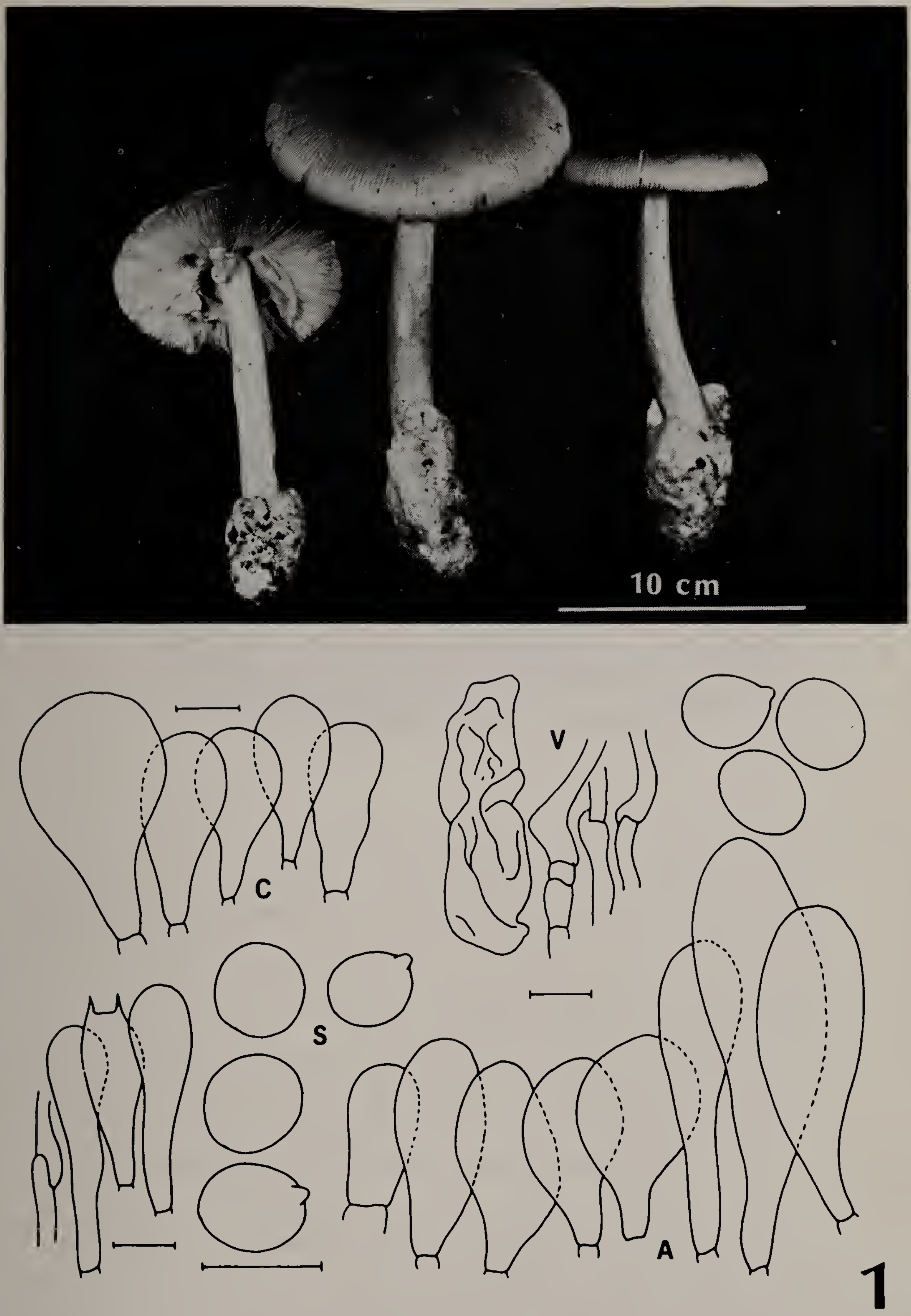

Fig 1. *Amanita umbonata.*

July 1976; ACAD 11926, Agriculture Centre, Kentville, Harrison, 9 Aug. 1977; ACAD 10216, south edge of Gaspereaux Valley, Kings Co., Grund, 11 Aug. 1973.

Comments: This fungus is a beautiful North American mushroom. These collections differ from the typical form in the prominent broad pileal umbo that remains reddish orange after the margins have faded to yellow. "Caesar's" mushroom is edible and choice, and easily identified. It is uncommon in Nova Scotia. Pomerleau (1966) reports *A. caesarea* var. *americana* from Quebec. Coker (1917, p. 19 & Pl. 110) described and illustrated a taxon without the broad umbo, indicating a different variety than the one described here.

Fig 2. *Amanita wellsii.*

Amanita wellsii (Murr.) Sacc.

Syll. Fung. 13: 2-3. 1925.

Venenarius wellsii Murr. Mycologia 12: 291 - 292. 1920.
Amanita wellsii Murr. Mycologia 12: 292. 1920.

Figure 2

Basidiocarp: Pileus 3-5 cm broad, convex, expanding to plane with slightly rounded margins; surface glabrous with minute yellowish remnants of universal veil on disc, at times subviscid; margins glabrous, nonstriate, in age becoming rimose, fragments of pellicle sometimes pendant on margins; color apricot orange ("Ochraceous-Salmon"; ISCC-52 - light orange; to "Pale Ochraceous-Buff"; ISCC-92-yellowish white), uniform; context compact, firm, pale yellow, orange under pellicle, unchanging, taste and odor lacking. Macrochemical reactions of the pileus: phenol-aniline - brown under pellicle; aniline - light purple under cuticle; phenol - brown under cuticle. Lamellae 8-10 mm wide, pale yellow ('Massicot Yellow"; ISCC-89 - pale yellow), lamellulae lacking. Stipe 4-9 cm long, 9-15 mm thick, mostly equal, slightly expanded basally, base sometimes bulbous; surface covered with fine floccose scales, furfuraceous above annulus, becoming nearly glabrous below; color ("Maize Yellow"; ISCC-89 - pale yellow) at apex, becoming ("Tawny-Olive"; ISCC-94 - light olive brown) at base; annulus superior, of loosely woven hyphae that may hang free or adhere to stipe; volva reduced, floccose scales of loosely interwoven hyphae, often sloughing away in age or when picked; caulopellis firm and yellow; context soft and white, stuffed, becoming hollow in age, unchanging.

Spores 12-13 x 7-8 (9) μm, ovoid to ellipsoid, smooth, thin-walled, hyaline in KOH, nonamyloid, apiculus apical to sublateral. Basidia 35-55 x 10-13 μm, clavate, thin-walled, 4-spored. Pseudocystidia marginal cells (Bas 1969, p 322) 70-80 x 13-15 μm, clavate, subventricose, apices rounded, thin-walled, rare. Annulus of loosely interwoven hyphae; terminal cells 30-55(75) x 18-25 μm, clavate, ventricose to subovoid, thin-walled; hyphae 5-16 μm thick, thin-walled; no clamps observed. Pileipellis a thin turf (trichodermium) of non gelatinized hyphae mostly 4-6 μm thick overlaying a subcutis of yellow interwoven hyphae 100-120 μm thick. Pileal context of tightly interwoven hyphae 7-15 μm thick. Lamellar trama slightly bilateral, of thin-walled hyphae 8-10 μm thick; subhymenia not observed.

Habitat: Growing singly in gravel and bare soil along roadside cuts and shoulders.

Material Examined: ACAD 13102, Bay St. Lawrence, Cape Breton I., J. Timpa, 20 Aug. 1979; ACAD 13111, Kentville, Kings Co., Harrison, August 1979.

Comments: This is the first report of this beautiful light-orange mushroom from Nova Scotia; however, Jenkins (1977) provides a description and color illustration for material from New England and North Carolina.

Amanita rubescens (Fr.) S.F. Gray

Nat. Arr. Brit. Pl. 1: 600. 1821.

Agaricus rubescens Fr. Syst. Myc. 1: 18. 1821.
Venenarius rubens Murr. Mycologia 5: 75. 1913.
Amplariella rubescens (Fr.) Gilbert. Iconogr. Mycol. Milano 27, Suppl. 1, p 78. 1941.

Figure 3

Basidiocarp: Pileus (3)4.5-10(11) cm broad, convex to ovoid when young, expanding to broadly convex then finally to almost plane with margin broadly rounded, sometimes with a low broad umbo; surface glabrous and sticky (subviscid), with floccose scales that are remnants from the universal veil; margins incurved at all ages, pellicle separable, slightly striate in some specimens; color variable from nearly whitish red to reddish, (9A2 - reddish white; ISCC-7 - pale pink; 9B4 - dull red; ISCC-18 - light grayish red), the disc often darker than margins, warts dingy whitish or stained reddish; context pallid white, changing to reddish upon exposure and injury, soft; odor and taste not distinctive. Lamellae free, close, with 2 series of lamellulae, ivory white, stained reddish or pink. Stipe (8)10-16 cm long, 0.7-1.2 (1.5) cm thick, mostly equal or tapering slightly toward apex, base bulbous, bulb 1.5-2.5 cm broad; surface of apex fibrous and minutely floccose or pruinose, sometimes slightly striate, mostly minutely fibrous or floccose or subglabrous below annulus to bulbous base, annulus superior, moderately thick, soft, delicate, white and sometimes stained pinkish; stipe white with pinkish tints to brownish at apex, becoming mostly pallid toward base, bruising pinkish and reddish overall; volva evanescent, lacking or reduced to a few patches of scales adhering to bulb, remnants staining reddish.

Spores 8-10 x 6-7 μm, white, smooth, amyloid, globose, or subglobose to ellipsoid. Basidia 30-35 x 8-10 μm, clavate, thin-walled, mostly 4-spored, projecting beyond hymenium, hyaline in KOH or water. Pseudocystidia at edges of lamellae 20-30(35) x 12-25 μm, globose, clavate or ovoid, thin-walled. Pileipellis consisting of a viscid pellicle approximately 100-140 μm thick covering a sublayer of interwoven hyphae approximately 80-100 μm thick, hyphae in this layer containing reddish-brown membrane pigment. Pileal context of interwoven irregular hyphae, mostly 20-30 μm thick, interspersed with narrow (5-7 μm) cells; clamps infrequent. Lamellar trama composed of bilateral mediostratum of thin-walled hyphae mostly 12-20 μm thick, and a subhymenium approximately 20-25 μm thick consisting of spherical, oval, or inflated irregular cells mostly 10-25 μm broad. Annulus of interwoven hyphae 3-5 μm thick; occasionally with large, embedded sphaerocyst-like cells resembling the pseudocystidia found in lamellae. Volva of collapsed ovoid cells, thin-walled, 40-100 x 25-40 μm, and thin-walled hyphae mostly 4-5 μm wide; clamps not observed.

Habit and Habitat: Solitary, scattered to gregarious, in coniferous woods or under oaks.

Material Examined: ACAD 10365, Alpena Rd., Inglisville, Annapolis Co., Boyd Gehue, 7 Aug. 1979.

Comments: Amanita rubescens is common in Nova Scotia and while it is listed as edible no one in our immediate circle of friends has had the courage to test it. One reason is that it is an extremely variable species as it grows around Kentville with numerous morphological and color variants that indicate an unusually wide genetic make-up. These variants range from forms that are strongly reminiscent

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Fig 3. *Amanita rubescens.*

of *A. flavorubens* to others that are almost white with only the faintest blush of reddish colors. This is particularly true on a lawn in Kentville shaded by huge red oaks where there is an abundance of *A. virosa, A. bisporigera, A. flavorubens,* and *A. flavoconia* growing whenever conditions are favorable. Possibly a chemist can be found to test the numerous variants for poisons.

This is a beautiful and distinctive amanita, particularly as it grows in the spruce and hemlock forests, and it can usually be easily identified. However, this taxon requires additional field data on the numerous forms under oaks before we can be certain that gene exchange is not occurring with other species.

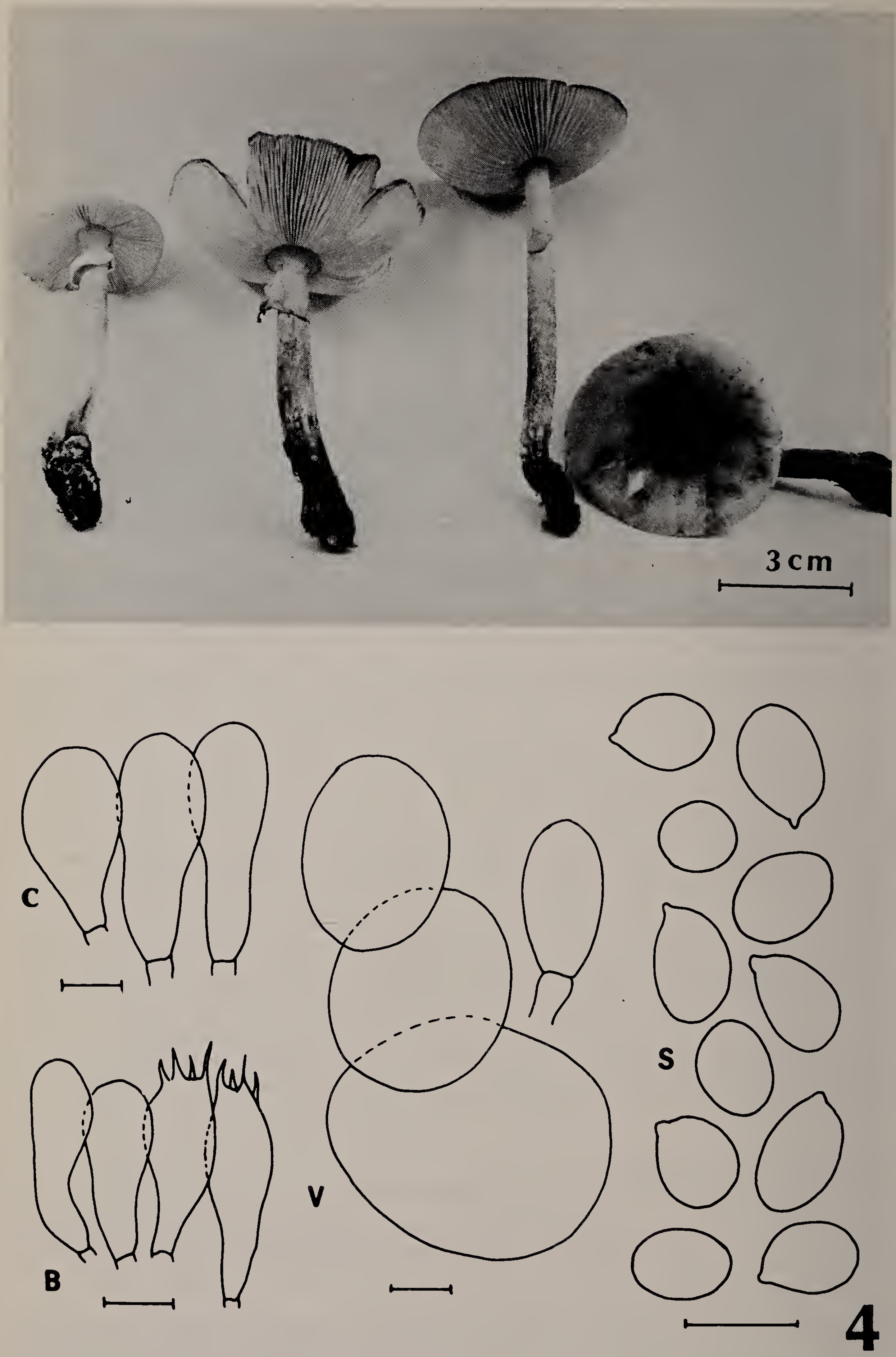

Fig 4. *Amanita flavorubens* var. *gracilis*.

Amanita flavorubens Berk. & Mont. in Mont.
Syl. Gen. Spe. Crypt. Paris 1846
var. gracilis var. nov.

A. flavorubescens Atk. J. Myc. 8: 111. 1902.

Figure 4

Pileus 3.5 - 6 cm latus, convexus et expansus, melleus, glaber, non striatus; lamellae liberae, confertae; stipes 7 - 9 cm longus, 5 - 8 mm crassus, pruinosus; annulus membranaceus, pallidus; volva evanescens. Sporae 7 - 9(10) x (5)6 - 7 μm, subglobosae vel subellipsoidae, amyloideae. Typus in herbario E.C. Smithii, Universitatis Acadiae (ACAD) conservatus.

Basidiocarp: Pileus 3.5 - 6 cm broad, convex becoming depressed on disc at maturity, finally margins uplifting in old age; surface glabrous, sometimes with a few yellowish remnants of universal veil, polished when dry; margins at first entire, splitting radially in age or when dry, nonstriate, somewhat frayed at edges in old age; color light brown (5D5 - clay; ISCC-72 - dark orange yellow) on disc, fading to light brown (5D4 - blond; ISCC-76 - light yellowish brown) at margins, all colors darkening in old age; context white becoming light brownish in age, yellowish under cutis at pileal apex; taste and odor not distinctive, chemicals on flesh negative in all reactions. Lamellae 2.5 cm broad, 3 mm wide; close, free, in 2 series, pallid. Stipe 7-9 cm long, 5-8 mm thick at apex, equal to slightly expanded basally; volva reduced to yellow floccose remnants; annulus white, superior, membranous, collapsing in age, usually adhering to stipe; surface pruinose on apex above annulus, mostly glabrous with thinly overlain fibrils or pruinae resulting from adhesion of veil remnants, often glabrous in age, fibrous when handled, brownish becoming reddish in lower half; context white in center, caulopellis off-white, staining brownish at base, stuffed becoming hollow in old age.

Spores 7-9(10) x (5)6-7 μm, subglobose, oval, subellipsoid to obovoid, amyloid, thin-walled, smooth, colorless in KOH, with medium-sized apiculus. Basidia 27-30 x 10-12 μm, thin-walled, hyaline in KOH, mostly 4-spored. Cystidioid cells on edges of lamellae (marginal cells) 25-35 x 12-15 μm, projecting beyond hymenium, mostly clavate, uncommon to rare. Lamellar trama bilateral, composed of inflated thin-walled hyphae mostly 70-90 x 25-40 μm, elongate, reniform, subfusoid to ellipsoid; subhymenium mostly 10-25 μm thick, of sub-globose or ovoid cells. Pileal context of interwoven thin-walled hyphae 5-8(10) μm wide, and large thin-walled, elongate, reniform, or ovoid hyphae mostly 80-100 x 30-40 μm, many containing gas when mounted in water; clamps not observed. Pileipellis a layer of mostly gelatinized hyphae 80-100 μm wide, the nongelatinized cells 205 μm wide. Cells in the volvar remnants 40-70 x 10-35(40) μm, clavate to mostly ovoid, interspersed with loosely interwoven thin-walled hyphae 3-5 μm wide.

Habit and Habitat: Solitary to gregarious in grass under red oaks (*Quercus borealis* Michx.).

Material Examined: ACAD 13019 (Type), Kentville, Kings Co., Harrison, 19 July 1979.

Comments: Amanita flavorubens is a highly variable taxon. *Amanita flavorubens* var. *gracilis* differs from variety *flavorubens* in its long, slender, deep-rooting stipe that lacks a defined volva, and a glabrous pileal surface. The volva is a mass of yellowish scales and remnants from the universal veil that fall away and remain in the ground upon picking. *Amanita flavorubens* is uncommon in North America but is abundant under red oaks in Kentville, N.S. This gracile variety is probably the least common and most distinctive of several varietal forms that remain to be described.

Amanita vaginata Bull. ex Fr.) Vitt. sensu lato

Tent. Mycol. s. Ama. Illust. Medi. 1826.

Vaginata fulva (Fr.) A.H. Smith. Mushrooms in their Natural Habitats, p 396. 1949.
Amanita vaginata var. *fulva* Gillet. Les Hymenomycetes, p 51. 1874.
Amanita vaginata subsp. *fulva*. Konrad & Maubl. Icon. Sel. Fung. 6: 33. 1924.
Amanita vaginata f. *fulva* Veseley. Atlas Champ. Eur. fasc. 4-5: 49. 1934.
Amanita fulva Secr. Mycogr. Suisse 1: 37. 1833 (invalidated).
Amanitopsis vaginata (Fr.,) Roze, Bull. Soc. Bot. France 23. 1876.
Amanitopsis vaginata var. *fulva* Sacc. Syll. Fung. 5: 21. 1887.
Amanitopsis fulva Fayod. Ann. Sci. Nat. Ser. 7, 9: 317. 1889.

Figure 5

Basidiocarp: Pileus (3)4.5-7.5 cm broad, at first conic becoming convex, then plane, and finally centrally depressed in old age, prominently umbonate; margins deeply striate to sulcate; glabrous slightly viscid (sticky when held to lips); color (5F4 - dark brown; ISCC-78 - dark yellowish brown to 7D8 - burnt sienna; ISCC-72 - dark orange yellow; "Cinnamon") at the margins; context thin, soft to brittle, white, unchanging; taste and odor not distinctive. Chemicals on pileal sections: formalin - pink; guaiac - lamellae green; $FeSO_4$ - gray; guaicol - vinaceous purple; phenol aniline - commencing as a vinaceous reaction directly above lamellae, becoming deep reddish brown; phenol - deep reddish brown. Chemical reactions on cutis all negative. Lamellae white or pallid, becoming orange gray when old, close, free, broadest at margin, edges finely irregular. Stipe 8.5-15 cm long, 5-8 mm thick, mostly equal or sometimes tapering apically; surface pruinose, or squamulose to sometimes subfribrillose; color that of the pileal margin, usually a shade of light orange; annulus absent; volva membranous, tightly sheathing, grayish to grayish orange, usually with brown or cinammon stains or spots; context white with firm rind, stuffed becoming hollow, finely floccose on interior walls of rind.

Spores 8-10 μm, globose, smooth, nonamyloid, hyaline in water. Basidia 45-60 x 10-15(18) μm, clavate, thin-walled, 2- or 4-spored. Pileal surface a turf about 250-300 μm thick of interwoven irregular hyphae 6 x 10 μm broad, subgelatinous, with brown intracellular pigment in most hyphae. Pileal context of interwoven, irregular, thin-walled hyphae mostly 15-25 μm wide. Lamellar trama composed of a mediostratum and subhymenium, the bilateral medio-stratum of large subclavate cells about 25-30 μm wide, the subhymenium of spherical, oval, or ellipsoid thin-walled cells mostly 15-20 μm diameter. Volva of interwoven hyphae mostly 4-6(10) μm thick, terminal cells 20-30 x 10-20 μm that are globose or ellipsoid, and sphaerocysts (20)30-40 μm, thin-walled and usually collapsed when mounted in water.

Habit and Habitat: Gregarious in coniferous or mixed forests, often growing in *Sphagnum*.

Material Examined: ACAD 10327*, Port Williams, Kings Co., Harrison, 27 July 1979; ACAD 11779, Auburn, Kings Co., Harrison, 11 Sept. 1976; ACAD 10944, Buckfield, Queens Co., H. Stewart, 20 Aug. 1966; ACAD 10990, Hebb's Cross. Lunenburg Co., H. Stewart, 28 Sept. 1966; ACAD 1088, Aylesford, Kings Co., H. Stewart, 29 July 1967.

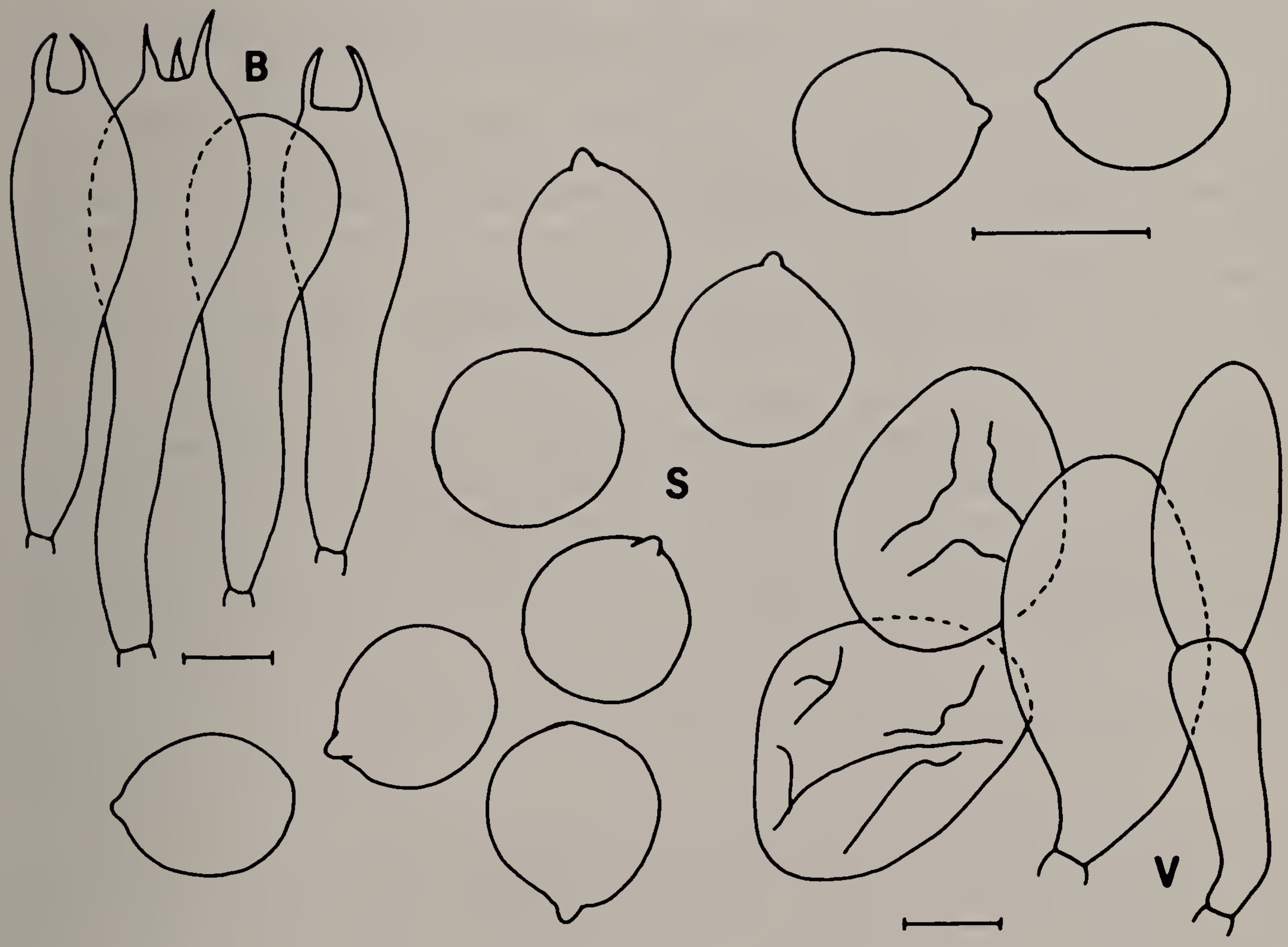

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Fig 5. *Amanita vaginata.*

Comments: Although we present here a description for the most common variety with the brown cap (*A. vaginata* var. *fulva*) we choose to use the name *A. vaginata* (Bull. ex. Fr.) Vitt. for all the varieties until a nomenclatorial type is selected to define the taxon *vaginata*. We believe that the Nova Scotian varieties (*fulva, alba, livida*) will be autonomous species when the status of *A. vaginata* is elucidated.

Acknowledgements

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CORTINARII OF NOVA SCOTIA. I. TAXA IN THE SUBGENUS DERMOCYBE (FR.) FR.

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This is a preliminary report following 2 years' collecting of the subgenus Dermocybe of the genus *Cortinarius*. It has proved to be a large and complex group in Nova Scotia. Only 8 taxa are treated in detail, with *C. rubeus* and *C. pseudotubarius* described as new species. A surprising number of variants obtained during this study remain to be described in detail, but further collections are needed before their exact position in the subgenus *Dermocybe* can be established firmly.

Deux années de prélèvement du sous-genre *Dermocybe*, genre *Cortinarius*, amènent les auteurs à présenter un rapport préliminaire sur ce groupe s'avérant vaste et complexe en Nouvelle-Écosse. Deux nouvelles espèces, *C. rubeus* et *C. pseudotubarius*, sont décrites parmi les huit seuls taxons exposés en détail. Une quantité surprenante d'autres variations a été recueillie et celles-ci demeurent encore à décrire. Cependant, d'autres prélèvements sont nécessaires avant d'établir avec certitude leur position à l'intérieur du sous-genre.

Introduction

Dermocybe is a difficult subgenus of the large, complex genus *Cortinarius*, which is not well known east of the Great Lakes. The subgenus has rather small basidiocarps with slender, equal, or slightly clavate stipes. The pilei, when young, are globose to subglobose, expanding to campanulate, often sub-hygrophanous (darker after heavy rains), and their surfaces are silky, and glabrescent. Pileal colors are reddish, yellowish, olivaceous, or cinnamon brown. The lamellae are yellow, orange, red, greenish olive or olive-brown. The stipe apex is frequently concolorous with the young lamellae. Buttons are enclosed by a universal veil that may or may not be concolorous with the cortina and may persist on the pileus and stipe. The context is pigmented and, when tested with KOH, will give either a red, brown, or black reaction. All species have been found to contain various combinations of anthrachinonic pigments that are either vacuolar or in interhyphal granules. Moser *in* Singer (1975) says "The presence of endocrocin is characteristic and diagnostic for all *Dermocybes*" and admits some 50 species when treating the group as a genus. He mentions 13 other pigments found in the various stirpes. Scientifically it is of great interest to base a genus on the presence of a group of chemicals, but it is doubtful if such procedures will stand the test of time. Such chemical tests are useless for practical identification under normal field conditions.

Kauffman (1918; 1932) was the first to provide a concept for species of *Cortinarius* in North America, which was based on the works of E.M. Fries (1821; 1838; 1874). Wehmeyer (1950), following Kauffman, identified his *Dermocybe* collections from Nova Scotia as *Cortinarius cinnamomeus, C. sanguineus, C. semisanguineus* and *C. malicorius*.

Ammirati (1972; 1975; 1977) critically studied various taxa from the Pacific Northwest and the Great Lakes, and also included a few collections from Nova Scotia. We have been closely following his publications during our studies. The collections of *Dermocybe* from Nova Scotia indicated that the flora of the region warranted further study, and this paper is based on collections obtained during two fruiting seasons. In 1978 there were few dermocybes but in 1979 they were abundant and considerable data became available. Inconsistent and unpredictable production of basidiocarps from year to year, and the relatively short fruiting period of some species limits the amount of information that can be obtained in any one season. We also found that the time required to make critical descriptions, color notes, macrochemical tests and comparative studies of young and mature specimens limit the number of collections that can be studied during a fruiting season.

There is 1 collection of *C. sanguineus* from Nova Scotia in the E.C. Smith Herbarium at Acadia University. This species was not found during the 1978 and 1979 collecting seasons. We have included the species description given by Ammirati (1972), but the microscopic features given are from the Nova Scotian collection.

History and Nomenclature

Fries (1821) named *Dermocybe* as a tribe in the series *Cortinaria* of the genus *Agaricus.* The tribe consisted of variously colored species with dry, cobwebby veils, and dry, fibrillose, more or less fleshy (rarely viscid) pilei that were convex, subumbonate, or conically expanded, with stipes hollowed, firm and subequal. The original tribe was divided into 4 subtribes based on the nature of the pileal surface, attachment of the lamellae, the color of the basidiocarp, and the habitat. These subtribes were: (l) *Raphanoidei* Fr. with 16 species, (2) *Leucopodii* Fr. with 9 species, (3) *Lysiophylli* Fr. with 6 species, and (4) *Lignatiles* Fr. with 2 species. Later, Fries (1838) revised the tribe *Dermocybe,* deleting the subtribal names and dividing the tribe into 4 groups based on the color of the lamellae.

Wünsche (1883) elevated the tribe *Dermocybe* to the rank of genus and recognized the limits of the tribe established by Fries (1838). Cooke (1871), Rabenhorst (1884), DeBary and Rehms (1884), Saccardo (1887), Smith (1893), Massee (1902), Rea (1922), Kauffman (1918; 1932), and Henry (1935) recognized the subgenus *Dermocybe* (Fries) Fries of *Cortinarius,* and for the most part followed the limits of the tribe established by Fires (1838).

Singer (1951) recognized the subgenus *Dermocybe* (Fries) Fries, and accepted the limits of the tribe *Dermocybe* in Fries, (1838), and, at the same time, selected *C. cinnamomeus* (L. ex Fries) Fries as the type species of the subgenus. Ammirati (1972) suggested that the correct author citation for the type species should be *C. cinnamomeus* (Fries) S.F. Gray, as Gray (1821) placed *'cinnamomeus'* in *Cortinaria* in 1821.

Kühner and Romagnesi (1953) recognized a subgenus *Dermocybe* and subdivided it into several groups ("groupe") on the basis of the basidiocarp pigmentation and spore shape. Two of the groups, *Sanguinei* and *Cinnamomei,* were separated in part on the basis of interhyphal pigment granules.

Moser *in* Singer (1975) separated *Dermocybe* (Fries) Wünsche from *Cortinarius* Fr. as a genus on the basis of the presence of anthrachinonic pigments, with *D. cinnamomeus* (L. ex Fr.) Moser as the type. He divided the genus into 2 subgenera *Icterinula* Moser & Horak and *Dermocybe.* The first subgenus was divided into section *Icterinula* with 3 stirpes, and section *Pauperae* with 2 stirpes. The subgenus *Dermocybe* was divided into 4 sections, *Holoxanthae, Dermocybe, Malicoriae,* and *Sanguinea.* Section *Dermocybe* had 3 stirpes and *Sanguinea* had 4, while the other 2 sections were not divided.

Shaffer (1968) did not recognize a subgenus *Dermocybe.* He described a subgenus *Cortinarius* with 4 sections. Species previously included in *Dermocybe* were listed in the sections *Sanguinei* and *Annulati*. Shaffer did not give author citations for any of the subgenera or their respective subsections.

Ammirati (1972, 1977) made the most recent and comprehensive study of the group in North America, and recognized *Dermocybe* (Fr.) Fries as a subgenus of the genus *Cortinarius* Pers. ex S.F. Gray. His work was based on a thorough study of macro- and microscopic features, a critical hyphal analysis, and macrochemical color reactions with various chemical reagents. *Dermocybe*, in his treatment, corresponds with Fries' (1838) third group: species with shiny cinnamon, red or yellow lamellae. Ammirati did not divide the subgenus *Dermocybe* into formal taxonomic groups; rather, he considered the divisions as "stirpes", a system of natural classification to be refined when the taxon is monographed for North America.

Habit, Habitat, and Distribution

Many dermocybes occur singly to gregariously along the edges of forest paths or woods roads. The basidiocarps are terrestrial; however, some species (*C. semisanguineus* and others) are rarely found growing on well-decayed conifer wood. *C. huronensis* occurs in *Sphagnum*-conifer bogs, and other species, such as *C. malicorius* and *C. semisanguineus*, may also occasionally grow in this habitat.

Many species of *Dermocybe* are considered to form mycorrhizae with forest trees. The taxa considered in this study are associated with the coniferous genera *Abies, Larix, Picea, Pinus,* and *Tsuga*. *C. semisanguineus* and *C. huronensis* grow with several genera, while others may have more restricted habitats. Two species are known to occur with broad-leaf trees: *C. uliginosus* Berkley with *Salix* and possibly *Alnus*, and *C. purpureus* (Fries) Maire with the genus *Quercus;* however these were not collected in Nova Scotia during the course of this study.

Dermocybes fruit from late August to early November, but dry weather may cause a poor fruiting season, as happened during the late summer and autumn of 1978. Abundant moisture can cause species such as *C. semisanguineus* and *C. huronensis* to appear earlier than normal.

Dermocybes have been collected throughout North America, South America, Europe, and Australia, but it is impossible to give meaningful distributions for them. For some taxa, there are only a few collections, and this indicates only where mycologists have collected, rather than an actual distribution of the species.

Materials and Methods

Field notes and photographs were taken as soon as possible for each collection. Kodachrome color transparencies were usually taken in the field in full sunlight, with a Pentax single lens reflex camera fitted with a 55 mm Super-Takumar lens.

The color of the pileus, lamellae and fibrils on the stipe base are important characters in the taxonomy of *Dermocybe*. Specific color designations that are capitalized and placed in parentheses are from R. Ridgway, *Color Standards and Color Nomenclature* (1912). Spore prints on white paper were given collection numbers, placed in envelopes, and refrigerated over silica gel to prevent the spores from collapsing.

The macrochemical color reactions of 2.5% KOH and 10% $FeSO_4$ w/v aqueous solution, were recorded on fresh and dried material. A drop of each reagent was placed directly on the pileal surface or context, and occasionally on the lamellae or stipe. Any color change or lack of one was recorded after 5 minutes. For many of the collections, both young and mature basidiocarps were tested.

Microscopic characters were obtained from sections prepared from dried specimens. The basidiocarps were saturated with 70% ethanol for a few minutes, then placed in distilled water for about ten minutes until the tissues were pliable.[1] Microscopic examinations of the pileus and stipe were made from thin sections mounted in H_2O, 2.5% KOH, and Melzer's Reagent. Sections cut tangentially from the pileus were used to study the hyphal arrangements of the pileal surface and lamellae. Longitudinal sections were used to study the stipe trama. Tissues of the lamellae were also examined by crushing a small section of the gill under a coverslip and the shape, measurements and color of the individual cells determined. These tissues were hydrated in 2.5% KOH and stained with 1% aqueous solution of phloxine.

Interhyphal pigment deposits were examined in 2.5% KOH, H_2O, and in Melzer's Reagent (hereafter referred to as Melzer's). Color reactions of the hyphae in KOH occur rapidly and were recorded immediately; no reactions to Melzer's were noted even after 10 minutes.

Measurements of the hyphal elements of the pileus, lamellae and stipe were made at a magnification of 400X. Spores, basidia, basidioles, and cystidia were measured at 900X, using oil immersion. The drawings for the text figures were made using a camera lucida, and collections used for text figures are marked with an asterisk (*).

The scanning electron microscope (SEM) used in this study was a JEOL J.S.M. 25. Spores from spore prints were mounted on adhesive copper tape (3-M) glued to a JEOL mounting stub with Duco cement (Dupont). The spores were coated in a Hummer II sputter coater with gold and palladium at approximately 20 nm thickness, in an Argon atmosphere at 10.5-13.5 Pa (80-100 millitorr) pressure, at 10 mA A.C. pulser for 2.5 minutes. The photo-micrographs were recorded on Polaroid Land Type PN 55 film, 4 in x 5 in, at magnification of 10,000X and 15,000X.

Macroscopic Features

Detailed field notes were obtained for all collections with particular attention to the color of the pileus, lamellae and stipe of both young and mature specimens. The following discussion outlines the nature and significance of the macroscopic features recorded.

Pileus

The diameter of the pileus varies from 1.5-7 cm but size is not a significant taxonomic character.

The pileus shape is subglobose, conic, to obtusely conic in the immature stage and usually expands to convex, plano-convex, to campanulate, and there may be a slight depression around the disc area. The margin is often incurved when young, and usually becomes decurved or plane when mature.

The surface is characteristically appressed fibrillose, in some becoming innately fibrillose or almost smooth and in others fibrillose scaly. Occasionally the surface becomes roughened or lacerate in age.

Color of the pileus is extremely important and there are diagnostic changes within a species which occur as the basidiocarp matures. By using the color of the mature pilei, the species in *Dermocybe* can be divided roughly into two groups: (1) those with an ochraceous to brownish surface and (2) those with a red

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[1] This paper, in an earlier form, was reviewed by J. Ammirati who suggests that some intrahyphal pigmentation could be lost by the use of ethanol. Herbarium material for sectioning should be hydrated slowly in a moist chamber.

to reddish orange surface. Among those with brownish pilei, there is a group of strongly olivaceous species. In these the pileus is yellow-olive when young, and becomes olive-brown or darker at maturity. The color of the pileus after a rain is usually a darker shade owing to the presence of water in the tissues.

The context of pilei in the different species varies from firm, to solid, moist, spongy, thin or moderately thick, and the color in most taxa is pale yellowish or rarely, yellow-olive, olivaceous or drab (e.g. C. *malicorius).* In age the color may be sordid or nearly concolorous with the surface of the pileus. Odor and taste vary and may be raphanoid, pungent, fragrant, or indistinctive, but are usually too indefinite to be useful for identifying species.

Lamellae

The lamellae are attached and most frequently adnate, sinuate, adnexed, or emarginate, and in age may secede. They are crowded, close to subdistant, and are moderately thin with edges even to serrate. These features are not particularly significant taxonomically.

The color of the young lamellae and the color changes that take place as the pilei mature are extremely important for the proper identification of *Dermocybe* species. Colors include cinnamon to cinnamon-orange, yellow, olive-yellow to olive, light orange, reddish orange, pink-orange, and bright to deep red. Changes in color with maturity are partly due to the development of the brown spores. One of the most striking color changes occurs in the species C. *subcroceofolius* Ammirati & Smith where the lamellae are at first yellow to dull olivaceous yellow and pass through yellow-orange to orange stages as they mature to brownish orange. The C. *subcroceofolius* complex is not treated in this paper but is present in Nova Scotia.

Stipe

Stipes in the section are usually slender (3-8 mm thick), and are equal or somewhat thickened near the base. The stipe length varies within species with recorded ranges of 3-10 (12) cm.

The stipe surface is characteristically appressed fibrillose, and often satiny or silky at the apex. It may also be sparsely fibrillose, or have patches or zones of dense fibrils from the universal veil.

The ground color is important at the levels of species and variety, especially in young specimens. The color is yellowish to olivaceous in most species, but a few are brownish olivaceous, reddish to rusty orange or deep red. In some the color changes as the basidiocarps mature. C. *incognitus,* for example, at first has a yellowish stipe which later becomes olivaceous, then brownish to dull reddish brown on the lower portion.

The color of the stipe base varies within some species. In C. *huronensis* var. *huronensis* it may be either olivaceous or tinted orange. In C. *semisanguineus* the base may be dull yellowish or shaded orange-pink to reddish.

The stipe context is usually solid when young, but often hollows in age. It is usually concolorous with the pileal trama, the stipe apex, or lower stipe surface, although it may differ from all 3. In age the context often discolors from the base upward. The interior color can be taxonomically important, but it is not a major character.

Universal Veil and Cortina

The cortina (partial veil) and universal veil are usually, but not always, similar in color. They may be inconspicuous but can be found on all taxa, especially when young. The hyphae of the cortina are cylindrical, usually 2.5-8 (10) μm wide, and are irregularly appressed on the stipe apex. The universal veil hyphae are similar though usually wider (3-12 μm), and slightly inflated. They are arranged longitudinally over the surface of the stipe, but may be interwoven. Their pigments and color reactions are similar to those of pileal cuticle and stipe cortex.

Microscopic Features

Pileus

Surface: The hyphae of the pileal surface are uniform throughout the subgenus. They are interwoven, more or less radially arranged, of cylindrical to broadly inflated cells 4-18 (23) μm wide and with walls to 1 μm thick. The end-cells are either rounded or tapered. Pileocystidia are lacking. In KOH, the hyphae may be hyaline, pale brownish, dark brown, to reddish-brown. This pigmentation and the microscopic color reactions are important characteristics of the surface hyphae. Often the microscopic color reaction is similar to the macrochemical color reaction.

Trama: The hyphae of the pileal trama are interwoven and more or less radially arranged, cylindrical to inflated, 2.5-20 μm wide, with walls 1. μm thick. The reactions of the tramal tissue of the pileus are usually similar to those of the basidia (q.v). In KOH they vary little among species the hyphae being usually hyaline with occasional colorless refractive granules or droplets, or slightly pigmented. In Melzer's the hyphae are hyaline, pale yellow or brownish-yellow from the color of the reagent.

Lamellae

Spores: The spores in *Dermocybe* are 5-12 x 3-6 μm. The adaxial view is elliptic to ovate with the surface finely to coarsely roughened but surface details cannot be seen under the light microscope. Under the SEM the ornamentation is of various patterns of irregular low warts, some of which are quite broad and connected by ridges of varying heights. The patterns are difficult to describe but show distinct differences in the area covered, the pattern around the apiculus and the minor roughening of the surface of the spores between the larger ornamentation. In 2.5% KOH the spores are yellowish to light brown, or ochraceous brown. Amyloid and dextrinoid reactions in Melzer's are absent.

Basidia: Basidia are 20-40 x 5-10 μm, with walls hyaline, thin, usually under 1 μm. In KOH they may be slightly brownish with a few refractive granules or droplets. In Melzer's they take on the color of the reagent and are pale yellow to brownish-yellow. Basidioles are similar to the basidia except they rarely contain particles or pigments.

Cystidia: Pleurocystidia are lacking but cheilocystidia usually 12-25 x 6-18 μm present in some species. They are clavate to broadly clavate and usually wider and shorter than the basidia, with similar reactions in KOH and Melzer's.

Subhymenium: The hyphae of the subhymenium are compactly interwoven of flattened or cylindrical cells, 1.5-5.5 μm wide, with walls to 1. μm thick.

Trama: The lamellar trama throughout *Dermocybe* is uniform in structure, and is composed of subparallel to interwoven hyphae, of cylindrical to inflated cells, 2.5-23 μm wide, with walls up to 1. μm thick. Reactions of tramal hyphae to KOH and Melzer's are similar to those of the basidia.

Stipe

The hyphae of the stipe are parallel to interwoven, of cylindrical to inflated thin-walled cells, 2.5-20.5 μm wide. The pigmentation and color reactions in KOH and Melzer's are similar to those of the pileal and lamellar tramae. In some species the hyphae contain yellowish to yellow-orange or yellow-brownish droplets or refractive granules.

Basal Mycelium

The basal mycelium is a layer of irregularly interwoven and branched hyphae attached to the stipe base. Cells are cylindrical, 2-6.5 μm wide, and thin-walled. Pigmentation and color reactions in KOH and Melzer's are usually similar to but darker than in the pileus.

Universal Veil

Hyphae of the universal veil are usually longitudinally arranged and vary from subparallel to interwoven. The cells are cylindrical and occasionally are slightly inflated. Generally the pigmentation and color reactions in KOH and Melzer's are similar to those of the pileus surface.

Clamp Connections

Clamp connections are found in all the species described in this study, occurring in all parts of the basidiocarp, and are of the normal type.

Oleiferous Hyphae

These are distinctive hyphae containing oily refractive substances, and are found in most of the species described in this study. They appear to differentiate from the generative hyphae, but do not form a continuous system in any part of the basidiocarp. They occur in the pileal and lamellar tramae, stipe cortex, and basal mycelium. The pigmentation and color reactions in KOH are hyaline, grayish or yellowish. Oleiferous hyphae occur in most fleshy fungi and are not taxonomically significant in this study.

Interhyphal Pigment Deposits

Interhyphal pigment deposits are a distinctive feature of the section *Dermocybe,* but are not exclusively characteristic as they are present in other species of *Cortinarius* (Moser 1972). The deposits are granules of anthraquinone pigments (Gabriel 1959-1960). They are found in the pileus, lamellar trama, stipe cortex, and occasionally in the basal mycelium. The interhyphal deposits were observed in H_2O, KOH, and Melzer's, and are refractive, colored yellow to greenish, orange, red, red-orange, red-brown, and brownish. In KOH the deposits in some species give an initial reddish reaction, but this color diffuses and soon fades. KOH and Melzer's tend to dissolve portions of the deposits when studying dried specimens and the pigments are often more easily seen when mounted in H_2O.

The interhyphal deposits in the species described in this study were found to be of normal globular or particulate type (Ammirati, 1972). *C. cinnamoneoluteus* contained globular pigments as well as granules that exhibited a spiny or crystalline shape. These pigments were olivaceous and occurred throughout the stipe cortex and basal mycelium.

Macrochemical Reactions

KOH-Fresh Basidiocarps:

The color reactions with KOH are useful in grouping species but only when considered with other characteristics of the basidiocarp. There are three general categories of color reactions: (1) red, vinaceous, or reddish brown (2) violet-brown, purple, or blackish (3) olive-fuscous, fuscous brown and no reaction. The red to reddish brown reaction is the most common.

KOH-Dried Basidiocarps:

The KOH reactions of fresh and dried pilei were usually similar, except for *C. humboldtensis,* Ammirati & Smith (not discussed here), which gave a purple-brown reaction when fresh, and a deep brown to reddish reaction when dried.

$FeSO_4$ - Fresh Basidiocarps:

Usually the reactions on the pileal surface were negative or rarely watery brown. The pileal context, when tested, usually turned drab or olivaceous. *C. tilamookensis* Ammirati, nom. prov., is known to exhibit a green reaction (Ammirati 1972).

$FeSO_4$ - Dried Basidiocarps:

The reactions on the pileus and lamellae on those species tested were negative (no change) or gave a slight brownish reaction.

Cortinarius huronensis Ammirati & Smith var. huronensis

Mich. Bot. 11: 20-21. 1972

Figs 1, 7, 14

Basidiocarp: Pileus (0.5) 1.5-4.5 cm broad, convex to plano-convex, umbonate, slightly depressed around the disc; margin incurved to decurved, appressed fibrillose, dark yellow-brown (Yellow Ocher to Raw Sienna), dark brownish (Snuff Brown to Chestnut-Brown) to a grayish brown, or ochraceous tint, brownish overall in age and when moist, often streaked dull brown; context 0.5-0.25 cm thick at the disc, solid, firm to moist, light yellow (Picric Yellow to Buff-Yellow) becoming drab, watery and olivaceous, especially over the lamellae; odor and taste raphanoid to not distinctive; KOH reddish to dark reddish on surface, brownish black on surface and lamellae when dried. Lamellae 0.4-0.6 cm broad, sinuate or emarginate, seceding in age, close to subdistant, ventricose when mature, edges uneven and wavy; light golden yellow near (Strontian Yellow) to darker yellow-brown (Primuline Yellow to Yellow Ocher) and finally rusty golden with maturity of spores. Stipe 4.5-7.5 (8.5) x 0.3-0.6 cm, equal to slightly enlarged at the base, appressed fibrillose; apex satiny, light yellow (Mustard Yellow) to light olivaceous yellow, becoming duller yellow below; surface fibrils reddish brown to dark brown (Tawny to Cinnamon), tinted darker reddish brown on the lower stipe, above base brownish to olivaceous, often watery, light yellowish to creamy buff (Naples Yellow) at the base; context firm, slightly fibrous, stuffed becoming hollowed, at first yellow (Mustard Yellow to Amber Yellow), becoming drab or olivaceous toward the base, cavity tinted rust in some mature specimens.

Microscopic Features: Spores (7.7) 8.2-11(12) x (4.5)5-6 (6.6) μm, in face view ovate to elliptic, verruculose to rugose, in KOH light golden brown; under the SEM ovate to broadly elliptic, ornamentation of large irregular-sized warts fused into many patterns, spaces between with smaller warts and roughenings; apiculus base of a cone, 0.6 μm wide, 0.5 μm long, tip rounded with a depression, sides smooth, plagelike base. Basidia 25-28 x 6-8 μm, 4-spored, some quite long, clavate to broadly clavate, in KOH hyaline to yellowish, occasionally having colorless refractive granules and droplets; basidioles 18-24 x 6.6-8.8 μm, clavate, similar to basidia in details of contents. Cheilocystidia 17-20 x 11-13 μm, clavate to broadly clavate, hyaline to pale yellowish in KOH, often containing colorless refractive granules or droplets. Subhymenial hyphae compactly interwoven, of tubular to inflated cells 1-5 μm wide, walls 0.5-0.8 μm, in KOH hyaline, in Melzer's pale yellowish; tramal hyphae parallel to subparallel to slightly interwoven, of tubular to inflated cells 5.2-16 μm wide, walls 0.5-0.8 μm, in KOH hyaline to light brownish, in Melzer's pale yellow to light yellowish brown. Surface hyphae of pileus interwoven, radially arranged, of tubular to inflated cells, 5.2-13 μm wide, walls 0.1 μm, in KOH hyaline to light brownish, or with a reddish brown or orange-brown pigment, in Melzer's hyaline to light yellowish brown. Stipe cortex hyphae parallel to subparallel, to somewhat interwoven, cells tubular to inflated, 5.2-18.4 μm wide, in KOH hyaline to yellowish, in Melzer's yellowish to pale reddish; basal hyphae irregularly interwoven, narrowly tubular cells, branched, 3-10 μm wide, in KOH hyaline, often containing a yellowish or yellow-brown pigment. Oleiferous hyphae not observed. Interhyphal pigment deposits present in the trama of the pileus, the lamellae and the stipe cortex; in KOH yellow, orange, reddish to brownish, some dark brownish or brownish black granular pigments, in H_2O yellow-golden to reddish brown, in Melzer's yellow, yellow-orange, orange to reddish.

Habit and Habitat: Scattered to gregarious in *Sphagnum* and other mosses, in boggy areas or humus under conifers. September to October.

Material Examined: 13194, 1/10/78, Lake George, Kings Co.; 13197, Harrison, 14/10/78, Monastery, Antigonish Co.; 13198A, 2/9/79, Lake George, Kings Co.; 13201, 3/10/79, Aylesford, Kings Co.; 13275* 2/9/79, Lake George, Aylesford Road, Kings Co.

Observations: C. huronensis is a common species of conifer - *Sphagnum* bogs and moist or mossy coniferous woods. It was described from Michigan and possibly will be found throughout the northeastern parts of North America. The stipe base is often tinted dull orange or olivaceous, and is variable (Ammirati 1972). The collections in this study, especially those occurring in *Sphagnum,* were darker reddish brown but the slight color differences in the Nova Scotia material are considered within the variability of this species.

Cortinarius incognitus Ammirati & Smith

Mich. Bot. 11: 18 - 20, 1972

Fig 15

Basidiocarp: Pileus (0.7)1.5-4(6) cm broad, conic to convex, becoming plano-convex, umbonate to subumbonate, slightly depressed around the disc; margin incurved to decurved, thin, fragile, somewhat lacerate; surface dry to moist, velvety, appressed fibrillose to fibrillose-scaly, especially on the upper margin, having an ochraceous sheen from a thin coating of fibrils yellow-brown to golden brown (Yellow Ocher to Raw Sienna) to light medium brown (Buckthorn Brown) on the margin, medium dark brownish (Snuff Brown or Light Brownish Olive) to dark red-brown or dark olivaceous brown (Cinnamon-Brown to Sepia) on the disc, often dull to dark brown fibrils overall; context 0.2-0.7 cm thick, firm to soft, moist, pale yellowish to drab whitish buff (Maize Yellow to Baryta Yellow) becoming watery and darker yellowish or olivaceous in some specimens; taste and odor somewhat raphanoid to not distinctive; KOH reddish brown to dark reddish brown on pileus surface, on dried material deep red to blackish on pileus and lamellae. Lamellae 0.5-0.7 cm broad, sinuate, uncinate or emarginate to seceding in age, close to subdistant, ventricose, edges even to wavy; at first yellow (Light Cadmium to Primuline Yellow) becoming duller yellow or olivaceous (Yellow Ocher to Olive-Ocher) and finally brownish rusty, light (Cinnamon) as spores mature. Stipe 2-7 (8.5) x 0.3-0.6(0.7) cm, equal or enlarging slightly toward the base; apex satiny pale olivaceous to pale drab yellowish (Martius Yellow, Empire Yellow to Light Cadmium), ground color similar or duller, deep yellow-orange (Primuline Yellow), lower portions overlaid with rusty brown (Ferruginous) to dark brown (Cinnamon-Brown, Brownish Olive) to light brownish olive (Buffy Citrine) appressed fibrils; base dull, often watery, reddish orange (Orange Cinnamon) to more or less olivaceous or brownish drab (Cinnamon-Brown Sepia); context firm, slightly fibrous, stuffed becoming hollowed, often watery when mature, dull yellowish to yellow-orange, near (Martius Yellow to Empire Yellow) becoming dull to reddish-tinted at the base; cortina pale to dull yellow.

Microscopic Features: Spores (7.2)7.7-8.8(11) x 4.4-5(5.5) μm, in adaxial view long-ovate to elliptic, verruculose, in KOH hyaline to light brownish, in Melzer's pale yellowish to pale yellowish-brown; under the SEM, long-ovate to elliptic, ornamentation subdistant of variously fused warts and irregular ridges in complex patterns, a few small warts in some spaces between; apiculus 0.5 μm wide, 0.5 μm long, a broken cone with a projecting tab. Basidia 27-33 x 6-7 μm, 3- and 4-spored, clavate to broadly clavate, in KOH hyaline, pale yellowish, often with colorless refractive particles and droplets; basidioles 18-28 x 6-7 μm, similar to basidia. Cheilocystidia 10-14 x 6-9 μm, clavate to broadly clavate, in KOH hyaline to pale yellowish, in Melzer's pale yellowish. Subhymenial hyphae compactly interwoven, cells tubular to inflated, 2.6-7.8 μm wide, in KOH hyaline to light brownish, in Melzer's pale yellowish; tramal hyphae subparallel to interwoven, cells tubular, inflated, 4-13 μm wide, walls 1 μm, in KOH hyaline, pale yellowish or light reddish brown, in Melzer's yellowish. Surface hyphae of pileus interwoven, radially arranged, of tubular to inflated cells, 5-15 μm wide, walls 0.5-1 μm, in KOH hyaline to pale brownish or containing a reddish brown pigment, in Melzer's yellowish to yellowish orange-brown; tramal hyphae similar in size and arrangement of cells, hyaline to light brownish in KOH, in Melzer's pale yellowish. Cortical hyphae of stipe parallel to subparallel to interwoven, of tubular to inflated cells, 5-13 μm wide, walls 1 μm, in KOH hyaline, pale yellowish, or light brownish, in Melzer's yellowish; basal hyphae irregularly interwoven, branched, of tubular cells, 2-6.5 μm wide, walls 1 μm, in KOH hyaline to pale yellowish. Oleiferous hyphae present in the pileal trama, in KOH hyaline to grayish. Interhyphal pigment deposits present in the pileus, lamellar trama and the stipe cortex; in KOH orange-reddish to reddish brown, in Melzer's yellow-orange, orange to reddish.

Habit and Habitat: Single, scattered to gregarious in moss and leaf litter, under conifers, or in sandy pine areas. September to October.

Material Examined: 13212, 16/9/79, Aylesford Lake Road, Kings Co.; 13214, 28/9/79, Baxter's Harbour Road, Kings Co.; 13216*, 7/10/79 Millville, Kings Co.; 13217 and 13218, 14/10/79, Monastery, Antigonish Co.

Observations: C. incognitus is characterized by a yellowish to ochraceous pileus that becomes darker ochraceous to reddish-brown in age. The lamellae when young are distinctly yellow, but become duller yellow and finally rusty brown in age. The stipe is yellowish to brownish on the lower portions with reddish to dark brown surface fibrils. The stipe base is yellowish to olivaceous, and has not been observed with orange tones (Ammirati 1972). However, many of the collections in this study have reddish brown to rust tints at the base. *C. incognitus* in eastern North America may be confused with *C. huronensis* var. *huronensis,* but can be distinguished from the latter by its smaller spores. In most collections of this species the spores are 7-9.5 μm long, but a few larger ones may be present. There is also a slight variation in spore width. *C. incognitus* may also be confused with

C. wyomingensis Ammirati, nom. prov., which was described from the west (Ammirati 1972). The latter has smaller spores, and the lamellae, yellow at first, change to dull orange and then to rusty brown from the color of the spores.

Cortinarious malicorius Fries

Epicr. Syst. Mycol. 289. 1838

Dermocybe malicoria (Fries) Ricken, Die Blätterpilze. 160. 1915

Figs 2, 8, 16

Basidiocarp: Pileus 2.0-4.5 cm broad, conic to convex, becoming planoconvex, umbonate to subumbonate, slightly depressed around the disc; margin incurved to decurved, thin, more or less fragile, becoming lacerate in age; surface moist to dry, appressed fibrillose, having a reddish-ochraceous sheen from thin coating of fibrils, red-golden to reddish or rusty brown (Cinnamon-Rufous) to (Ferruginous) on the margin and disc when wet; dark reddish brown to dark brown (Russet to Chestnut) on the disc; context soft to firm, 0.3-0.8 cm thick at the disc, dull pale yellowish buff to dull olivaceous, (Tawny Olive); taste and odor slightly raphanoid to not distinctive; KOH deep red (Brick Red) to dark brownish red on the pileus context when fresh; on dried specimens, dark red brown to dark brown on surface and lamellae; $FeSO_4$—only specimen tested fresh gave a dark greenish olive color on the context. Lamellae 0.3-0.7 cm broad, adnexed, adnate to emarginate, close to subdistant, ventricose, ridges showing on the stipe apex when the lamellae are broken away, edges even to wavy; bright orange (Cadmium Yellow, Orange to Cadmium Orange), becoming rusty orange (Ochraceous-Orange) when spores mature. Stipe 3.3-7 x 0.4-0.8 cm, equal to clavate, becoming sub-bulbous at the base; surface appressed fibrillose, satiny to dull or deep yellow-orange, light (Primuline Yellow) having an ochraceous sheen overall; apex light yellow (Mustard Yellow), ground color similar, overlaid with rusty fibrils (Cinnamon) becoming slightly darker in older specimens; base pale to dull reddish orange, becoming more or less olivaceous in age in some specimens; context firm, somewhat fibrous, stuffed becoming hollowed, drab olivaceous to light brownish olivaceous at the base; cortina light to medium yellow. Universal veil remnants rusty (Orange-Cinnamon).

Microscopic Features: Spores 6-7 x 3.5-4.5 μm, in face view, elliptic to long-ovate, verruculose, in KOH light brownish, many having a large central guttula; under the SEM, ovate to elliptic, ornamentation sub-distant of irregular fused warts in complex patterns, interspersed with small ones, plage-like for 1 μm around apiculus; apiculus a very short base of cone, 0.5 μm wide. Basidia 25-28 x 5-5.5 μm, 4-spored, narrowly clavate, clavate to broadly clavate, in KOH hyaline, pale yellowish, to pale brownish, often having colorless refractive granules or droplets; basidioles 13-22 x 5.5-7.7 μm, clavate, similar in shape to the basidia, in KOH hyaline to light brownish. Subhymenial hyphae compactly interwoven, cells tubular, irregular to inflated, 2.2-4.4 μm wide, walls 0.5 μm, in KOH hyaline to light brownish or pale yellowish; tramal hyphae subparallel to interwoven, cells tubular to inflated, 6.5-17 μm wide, walls 1 μm, in KOH hyaline to light brownish or pale yellowish, in Melzer's yellowish. Surface hyphae of pileus interwoven, more or less radially arranged, of tubular to inflated cells, 5-13 μm wide, walls 1 μm, in KOH hyaline, light brownish, to pale vinaceous, in Melzer's yellowish to light yellow-brown; tramal hyphae interwoven, radially arranged, more so toward the surface, cells tubular, broadly inflated or irregular, 6.5-15.5 μm wide, in KOH hyaline to pale reddish brown, in Melzer's light yellow to light brownish. Cortical hyphae of stipe parallel to subparallel to slightly interwoven, cells tubular to inflated, 5.2-15.6 μm wide, walls 1 μm, in KOH hyaline, pale yellowish or light brownish, in Melzer's pale yellowish to light brownish; basal hyphae irregularly interwoven, branched, cells tubular, 1-4 μm wide, in KOH hyaline, pale brownish to reddish vinaceous. Oleiferous hyphae present in the basal mycelium, in KOH hyaline to pale yellowish. Interhyphal pigment deposits present in the pileus, lamellar trama, and the stipe cortex; in KOH dull yellow to orangeish, in H_2O yellow, orange to reddish brown, in Melzer's yellowish, orange, to brownish orange.

Habit and Habitat: Scattered, solitary to gregarious in moist conifer woods, leaf litter and moss. Late August to October.

Material Examined: 13191 and 13195*, 25/8/79, Caribou, Pictou Co.; 13219, 25/9/78, Caribou, Pictou Co.; 13220, 26/9/78, Caribou, Pictou Co.; 13221, 25/8/79, Caribou, Pictou Co.; 13223, 19/10/79, Canaan, Kings Co.

Observations: C. malicorius was one of the first dermocybes described by Fries (1838). The specimens as described by Ammirati (1972) are close to what Fries described although the general color is more orange and the pileus more reddish brown. Since no type specimen for *C. malicorius* has been selected (Ammirati 1972), and Fries gave no spore measurements, a problem arises in determining a spore size for this species. Kauffman (1932) and Moser (1967) closely follow the description as given by Fries, and agree on a small spore size for the species (5-7 x 3.5-4.5 μm). Other authors (Ricken 1915; Orton 1958) suggest a somewhat larger size.

Cortinarius rubeus sp. nov.

Figs 3, 9, 17

Pileus 2-3 cm latus, convexus vel plano-convexus, ad marginem incurvus vel decurvus et integer; siccus, appresso-fibrillosus demum fibrilloso-squamulosus, cinnamomeo-brunneus vel rufus; contextus 2-3 mm crassus, incarnatus; odor et sapor pungentes vel indistincti. Lamellae 3-6 mm latae, adnatae vel adnexae, confertae; aurantiacae demum brunneo-aurantiacae. Stipes 1.5-4.5 cm longus, 2-4 mm crassus, aequalis, pallido-ochraceus, rubiginosus fibrillosus; contexus firmus, excavescens. Sporae 6-8 x 4-4.5 μm ovatae vel ellipticae, verruculosae. Holotypus ACAD 13241, in sylva prope Aylesford, comitato Kings Nova Scotia lectus; in herbario E.C. Smithii, Universitatis Acadiae (ACAD) conservatus.

Basidiocarp: Pileus 1-3 cm broad, convex to plano-convex, somewhat depressed around the disc; margin incurved to decurved, thin, entire, becoming lacerate in age; surface dry, appressed fibrillose to fibrillose-scaly, especially on the upper margin, brown to deep reddish brown (Sayal Brown, Burnt Sienna, to Brick Red) on the margin, dark golden brown to dark rusty brown (Amber Brown, Clay Color to Cinnamon) on the inner margin, dark red-brown (Chestnut, Bay, to Mahogany) on the disc; context 0.2-0.3 cm thick at the disc, soft to firm, light brownish to brownish pink (Cream Color to Salmon Color); taste and odor pungent to not distinctive; KOH dark red-brown to dark brown (Chocolate) on pileus, deep red on context and lamellae, in dried material dark reddish brown on pileus, deep red on lamellae. Lamellae 0.3-0.6 cm broad, adnate, uncinate to sinuate or adnexed, close to subdistant, edges even to wavy; at first deep orange (Salmon-Orange) to brownish orange (Ochraceous-Orange), becoming rusty orange to reddish-shaded to brownish orange (Orange-Rufous to Orange-Cinnamon) when spores mature. Stipe 1.7-4.3 x 0.2-0.4 cm, equal, enlarging somewhat toward the base; apex satiny, light grayish brown (Ochraceous-Buff to Cinnamon-Buff); ground color similar, becoming more reddish (Vinaceous-Tawny), overlaid with scattered to dense rust-brown to deep reddish brown (Burnt Sienna, Morocco Red, Brick Red) fibrils concentrated toward the base; base drab buff to pinkish (Pale Orange-Yellow to near Cream-Buff to Vinaceous-Tawny) often tinted with bright red streaks (Rufous to Brazil Red); context firm, stuffed, sometimes hollow, light grayish brown to pale rusty (Light Ochraceous-Buff to near Cinnamon-Buff) or reddish at the base, near the surface reddish rust-brown (Burnt Sienna) to watery reddish orange (Vinaceous-Rufous). Cortina dull buff-yellowish (Ochraceous-Buff). Universal veil remnants reddish brown to rusty red (English Red).

Microscopic Features: Spores 6-8 x 4-4.5 μm, in adaxial view long-ovate to elliptic, verrucose, in KOH hyaline to light brownish; under the SEM long-ovate to elliptic, ornamentation close, of irregular fused warts in complex patterns, a few small warts in interspaces, slightly smoother toward the apiculus; apiculus base of an irregularly broken cone, 0.6 μm wide. Basidia 22-29 x 5-6 μm, 4-spored, clavate, in KOH hyaline, often containing colorless refractive particles or droplets. Subhymenial hyphae compactly interwoven, cells tubular to inflated, 2.2-4.4 μm wide, walls 0.5-1.1 μm, in KOH hyaline to light brownish, in Melzer's yellowish; tramal hyphae parallel, subparallel, to interwoven, cells cylindrical to inflated, 4.0-15.5 (19.5) μm wide, walls 0.5-1.1 μm, in KOH hyaline to light brownish, in Melzer's yellowish. Surface hyphae of pileus interwoven, of tubular to inflated cells, 3-18 μm wide, walls 0.5-1.1 μm, in KOH hyaline to brownish, dark brownish red, in Melzer's yellowish to orange-brown; tramal hyphae interwoven, of cylindrical to inflated cells, 4-16.5 μm wide, walls 0.5-1.1 μm, in KOH hyaline to light brownish, in Melzer's light yellow. Cortical hyphae of stipe parallel to subparallel, occasionally interwoven, cells tubular, inflated, 4-16.5 μm wide, in KOH hyaline to light reddish brown, in Melzer's hyaline, yellowish to golden yellow; basal hyphae irregularly interwoven, branched, cells tubular, 1.3-4 μm wide, in KOH hyaline to light reddish brown, having scattered red to reddish brown pigments. Oleiferous hyphae not observed. Interhyphal pigment deposits present in the stipe cortex and pileus trama; in KOH red to reddish brown, in Melzer's yellow, golden yellow, and orange.

Habit and Habitat: Scattered to gregarious in moss (*Polytrichum* sp.) on a sandy woods trail in October.

Material Examined: 13239, 3/10/79, Aylesford, Kings Co.; 13240, 7/10/79, Aylesford, Kings Co.; 13241*, 16/10/79, Aylesford, Kings Co.

Observations: *C. rubeus* is placed on the stirps Malicorius (Ammirati 1972) on the basis of spore size and KOH reaction. It is characterized by the reddish tones on the pileus and stipe, pink-red to orange-red lamellae, and distinctive red streaks and fibrils on the stipe surface.

Cortinarious sanguineus (Fries) S.F. Gray

A Natural Arrangement of British Plants. I. 629. 1821

Agaricus sanguineus Fries, Syst. Mycol. I: 229. 1821.
Cortinarius sanguineus (Fries) Fries, Epicr. Syst. 288. 1838.
Dermocybe sanguinea (Fries) Wünsche, Die Pilze. 125. 1877.

Figs 10, 18

"Pileus 1.8-4.5 cm broad, somewhat obtuse to convex or plane, disc more or less depressed, with the margin incurved to decurved, appressed fibrillose to minutely squamulose, sometimes splitting radially on the margin, disc rich red (Garnet Brown) to deep red (Maroon to Deep Garnet Brown) or tinted with colors of the margin, margin rich red (Garnet Brown to Ox-Blood Red) or duller red (Coral Red), sometimes streaked deep red to fuscous-red (Maroon to Victoria Lake). Context watery deep red (Maroon to Garnet Brown), where faded or beneath cuticle lighter red (near Coral Red); odor fragrant to mild or raphanoid, taste mild to raphanoid".

"Lamellae sinuate to broadly depressed with a more or less decurrent tooth, close, more or less ventricose when mature, edges uneven, at first rich red (Ox-Blood Red, dull Carmine, or Garnet Brown), becoming shaded rusty brown to dusky brown from the spores.

"Stipe 4.5-8.5 cm long, apex 3-9 mm, equal to a slightly enlarged base, fibrillose, shiny, rich red (Garnet Brown, Ox-Blood Red) or duller red (Coral Red), sometimes with watery deep red (Maroon) streaks, base or lower third dull ochraceous (Ochraceous Buff) or slightly tinted orange to reddish. Context stuffed to narrowly hollowed, rich red (Garnet Brown to Ox-Blood Red) throughout or deeper red (Maroon) in the lower portion, where faded paler red."

"KOH. Fresh basidiocarps: deep purplish red on the pileus surface. Dried basidiocarps: deep red to purplish red on the surface of the pileus, lamellae and stipe." (Ammirati 1972, p. 72-73).

Microscopic Features: Spores 7-9 x 4-5 μm, in adaxial view long-ovate to elliptic, verrucose to verruculose, in KOH golden brown, in Melzer's yellow-brown to orange-brown; under the SEM, ovate to broadly elliptical, ornamentation close, irregular-sized warts fused into various patterns; apiculus a diagonally broken cone 0.6 μm wide arising from a smooth plage-like area. Basidia 23-30 x 5-6.5 μm, 4-spored, clavate, broadly clavate to slightly ventricose, in KOH pinkish-red-pigmented, hyaline or containing colorless refractive granules or droplets; basidioles 12-25 x 5.0-7.7 μm, similar to basidia. Subhymenial hyphae compactly interwoven, cells tubular to inflated, 2.2-5.5 μm wide, walls 0.5 μm, in KOH pinkish red, in Melzer's yellow to golden yellow; tramal hyphae subparallel to interwoven, of tubular to inflated cells, 5-15.5 (20.5) μm wide, walls 0.5-1.1 μm, in KOH hyaline, light pinkish, pinkish red, or light vinaceous, in Melzer's deep yellow to orange-yellow. Pileal surface hyphae interwoven, more or less radially arranged, of tubular to inflated cells, 5-13 μm wide, walls 0.5-1.1 μm, in KOH hyaline, pinkish red to reddish brown, in Melzer's yellow to orange-brown; tramal hyphae interwoven, radially arranged toward surface, of tubular to inflated cells, 5-20.5 μm wide, in KOH light pinkish red, in Melzer's yellow to yellow-orange. Cortical hyphae of stipe longitudinally arranged, subparallel to interwoven, of tubular to inflated cells, 2.5-15.5 μm wide, in KOH hyaline to pinkish red or pale vinaceous, in Melzer's yellowish to yellow-orange to orange; basal hyphae interwoven, branched, of tubular cells, 2.5-5 μm wide, in KOH hyaline, deep pink, vinaceous, or red, with reddish globular pigments throughout. Oleiferous hyphae present in the basal mycelium. Minute pigment deposits present in the stipe cortex, basal mycelium, pileus, and lamellar trama; in KOH orange, red to red-brown, in Melzer's yellow, orange, red to red-brown.

Habit and Habitat: Single to scattered, conifer woods. September.

Material Examined: 2580, 30/9/53, Casey's Corner, Kings Co.

Observations: C. sanguineus is characterized by a deep red pileus, lamellae, and stipe. It has been collected previously in the province, but complete information is not available for the specimens. Further collecting and a detailed description of the color and macrochemical reactions of fresh specimens are needed. Cheilocystidia are reported from collections examined by Ammirati (1972); however, none were observed from the collection examined in this study.

Cortinarius semisanguineus (Fries) Gillet

Les Hyménomycètes. 486. 1874.

Agaricus cinnamoneus var. *semisanguineus* Fries, Syst. Mycol. I: 229. 1821.
Cortinarius semisanguineus (Fries) Kauffman, Bull. Torrey Bot. Club 32: 320. 1905.
Dermocybe semisanguinea (Fries) Moser, Die Röhrlinge und Blätterpilze. In Gams, Kleine Kryptogamenflora. 1: 174. 1955.
Dermocybe semisanguinea (Fries) Moser var. *alpina* Horak, Mitt. Schweiz. Anst. Forstl. Versuchswesen. 39: 80. 1963.

Figs 4, 11, 19

Basidiocarp: Pileus 0.7-5.5 (8.3) cm broad, conic to rounded-conic becoming convex, umbonate to subumbonate, often depressed around the disc; margin inrolled when young, becoming incurved to decurved, some uplifted and irregular, entire to lacerate or splitting radially; surface appressed fibrillose, dry-satiny, having an ochraceous sheen, golden ochraceous brown to yellow-brown (Yellow Ocher) on the margin, dark golden brown (Amber Brown), honey brown to deep yellow-brown (Ochraceous-Tawny) on the disc, in age becoming ochraceous brown to reddish brown fibrillose-streaked, young specimens often buff to golden yellow-tinted on the incurved margin; context 0.3-1.2 cm thick, firm, solid, dull light beige (Cream-Buff) to pale yellowish, becoming ochraceous under the cuticle; odor and taste pungent to not distinctive. Lamellae 0.5-0.8 cm broad, adnate to adnexed to emarginate, seceding in age, close to subcrowded, edges somewhat wavy, when mature ventricose; bright red (Carmine) to dull red (Brick Red) or deep red (Maroon), becoming rusty red-brown to cinnamon when spores mature. Stipe 2-8.5 x 0.3-1.4 cm, equal, tapered upwards, or clavate at the base, often covered with ochraceous to rust brownish appressed fibrils; apex satiny dull yellowish buff to light beige (Cream-Buff to Light Ochraceous-Buff), becoming darker to ochraceous at the base; base pale buff, often pinkish to orange-reddish-tinted (Grenadine to Apricot Orange), becoming sordid to olivaceous in age in some specimens; context stuffed or fibrous becoming hollowed, dull yellowish buff (Light Ochraceous-Buff) darkening toward the base; cortina (Pale Yellow). KOH inky black to vinaceous black on the fresh pileal surface, on dried material blackish on pileus and lamellae. $FeSO_4$ blackish on the pileal surface and lamellae of dried material.

Microscopic Features: Spores 7-8.5 x 4-5 μm, finely roughened to verruculose, in face view long-ovate to elliptic, blunt at the basal end, in KOH light brownish; under the SEM elliptic, ornamentation close, of complexly fused warts in various patterns, some small warts in interspaces; apiculus at an angle, with a depression in the broken end, base plage-like; Basidia 25-30 x 6-7 μm, 4-spored, clavate in ventricose, in KOH hyaline to pale yellowish; basidioles 13-25 x 3.0-5.5 μm, similar to basidia. Subhymenial hyphae compactly interwoven, of tubular cells, 2-4 μm wide, walls 0.5 μm, in KOH light reddish or vinaceous purple, more commonly hyaline, in Melzer's yellowish; tramal hyphae parallel, subparallel, to slightly interwoven, of tubular to inflated cells, 4-10.5 μm wide, walls 1 μm, in KOH hyaline or light vinaceous purple, often having purplish granules, in Melzer's yellowish. Surface hyphae of pileus interwoven, radially arranged, of tubular to inflated cells, 5-13 μm wide, walls 1 μm, hyaline to light reddish brown or light vinaceous purple, in Melzer's yellowish to yellowish brown; tramal hyphae interwoven, radially arranged especially near the surface, cells tubular, irregular and inflated, 7.8-13 μm wide, walls 1 μm, in KOH hyaline to pale yellowish, often containing purplish-pigmented particles, in Melzer's yellowish. Cortical hyphae of pileus parallel to interwoven, tubular, inflated, in KOH hyaline to light brownish, 5-15.5 μm wide; basal hyphae of tubular cells, irregularly interwoven, branched, 3-5.2 μm wide, containing some pigment globules, in KOH hyaline, reddish or purplish. Oleiferous hyphae present in the pileus and stipe trama. Interhyphal pigment deposits small, in the pileus, lamellar trama and the stipe cortex; in KOH yellowish to golden yellow, brownish, red-brown, in H_2O pale yellow to orangeish or reddish brown.

Habit and Habitat: Single, scattered to gregarious, occasionally cespitose, in conifer and mixed woods, occasionally on rotted wood or in moss. Late August to November.

Material Examined: 13243, 25/9/78, Caribou River, Pictou Co.; 13245, 14/10/78, Monastery, Antigonish Co.; 13246, 11/8/79, Aylesford, Kings Co.; 13247, 25/8/79, Caribou, Pictou Co.; 13248, 26/8/79, Caribou, Pictou Co.; 13249 and 13250, 31/8/79, Aylesford, Kings Co.; 13251 and 13252, 1/9/79, Harmony, Kings Co.; 13253, 2/9/79, Lake George, Kings Co.; 13254 and 13255, 12/9/79, Aylesford, Kings Co.; 13256 and 13257, 13/9/79, Aylesford Lake Road, Kings Co.; 13258, 30/9/79, Lake George, Kings Co; 13259 and 13261, 16/9/79, Lake George, Kings Co.; 13260, 18/9/79, Aldershot, Kings Co.

Observations: C. semisanguineus is common in conifer and mixed woods and is the most easily recognized species of *Dermocybe* in Nova Scotia. Some variation occurs in the color of the stipe and lamellae. In fresh specimens, stipes are medium yellow to ochraceous, with a characteristic pinkish to orange-reddish coloring at the base, and in age the stipe base may be olivaceous to drab. Similar variation in the color of the stipe base was observed in *C. huronensis* var. *huronensis* and in variants of *C. incognitus.* The color of the lamellae is a striking deep red, but in collections 13258 and 13261, the immature and mature lamellae were dull orange to rusty orange. It is possible that this form of *C. semisanguineus* is the result of early frost. The spores of the collections examined are consistent and within the published size-range for the species (Ammirati 1972). The only exceptions are the above-mentioned collections with orange-brown lamellae, with spores that were slightly larger. Further collecting and critical examination of the material should be done to establish the validity of frost effects.

Cortinarius cinnamomeoluteus Orton

Trans. Brit. Mycol. Soc. 43: 217. 1960.

Figs 5, 12, 20

Basidiocarp: Pileus 2.3-3.4 cm broad, convex to obtuse-umbonate; margin incurved to decurved, edge entire, splitting radially in age; surface dry, appressed fibrillose to velvety, buff olivaceous, pale (Deep Colonial Buff), margin paler (Colonial Buff), golden olivaceous (Tawny-Olive) on the disc, with dark brownish (Prout's Brown) fibrils overall; context 0.5-0.9 cm thick, firm, dull light beige (Cream-Buff), watery olivaceous above the lamellae; odor and taste not distinctive; KOH on fresh pileus brownish to reddish brown, on dried material dark brown on pileus, red-brown on lamellae. Lamellae 0.3-0.5 cm broad, sinuate to emarginate, edges roughened, wavy, close, olivaceous drab, dark (Straw Yellow, Honey Yellow to Olive Yellow) darkening when mature to (Aniline Yellow). Stope 3.5-5.5 x 0.5-0.8 cm, equal; surface dry, appressed fibrillose, apex dull, pale olivaceous buff (Colonial Buff), becoming duller olivaceous buff below (Deep Colonial Buff), streaked dull yellow, brownish golden (Aniline Yellow) becoming brownish tinted to olivaceous golden (Sayal Brown to Tawny-Olive) just above the base; base drab whitish buff (Maize Yellow); context firm, somewhat fibrous, stuffed becoming hollowed, dull light beige (Cream-Buff); cortina pale yellowish or light olivaceous-tinted, near (Straw Yellow).

Microscopic Features: Spores under the optical microscope 7-8 x 4-5 µm, in face view ovate to elliptic, verrucose to verruculose, in KOH hyaline or light greenish tinted; under the SEM, ovate, ornamentation distant, interspaces rough with small warts, principal warts large, 0.2 µm high, some fused into irregular ridges, smoother toward apiculus; apiculus a roughly broken cone, 0.5 µm wide, 0.4 µm long arising from a plage. Basidia 4-spored, 23-25 x 5-6 µm, clavate; in KOH hyaline or with brownish golden to olivaceous pigments, many with colorless refractive granules and droplets; basidioles 14-23 x 4.4-6.6 µm, clavate; in KOH hyaline or containing colorless refractive granules and droplets. Subhymenial hyphae compactly interwoven, of tubular to inflated cells 2.2-4.4 µm wide, walls 0.5 µm, in KOH hyaline to light brownish, in Melzer's yellowish; tramal hyphae parallel to subparallel, cells tubular, inflated, 6.5-18 µm wide, walls 0.5-1.1 µm, in KOH hyaline to light brownish, in Melzer's yellowish. Pileal surface hyphae interwoven, cells tubular to inflated, 5-10.5 (15.5) µm wide, walls 0.5-1.1 µm, in KOH hyaline to light golden brown, or brownish-tinted, containing pigmented particles, in Melzer's yellowish or orange-golden or light orange-brown; tramal hphae interwoven, of tubular to inflated cells, 5-18.2 µm wide, in KOH hyaline to light brownish, in Melzer's yellowish. Cortical hyphae of stipe parallel to subparallel, tubular somewhat inflated, 5-14.3 µm wide, in KOH hyaline to light brownish, in Melzer's pale yellowish to light brownish, having droplets or pigment granules scattered throughout; basal hyphae irregularly interwoven, branched, in KOH hyaline to pale yellowish. Interhyphal pigment deposits present in the stipe cortex, the basal mycelium, and the pileal and lamellar trama; in KOH yellow, golden olivaceous, brownish, in H_2O olivaceous, gray-brown to brownish, in Melzer's yellow, red, brownish, and olivaceous; in the basal mycelium and stipe cortex the pigments are crystalline or spiny.

Habit and Habitat: Single to scattered, in red pine woods (*Pinus resinosa* Ait.). October.

Material Examined: 13238*, 5/10/79, Aldershot, Kings Co.

Observations: C. cinnamomeoluteus is a distinctive taxon of subgenus *Dermocybe*. It is characterized by subtle olive-beige tones in the pileus and stipe, and has pale olivaceous yellow lamellae. On the basis of color, spore size and KOH reaction, *C. cinnamomeoluteus* belongs to the stirps Malicorius (Ammirati 1972). The pileus may at first be overlooked as a pale specimen of *C. semisanguineus* since they are of similar stature; however, they differ distinctly in the colors of the stipe and lamellae.

Cortinarius pseudotubarius sp. nov.

Figs 6, 13, 21

Pileus 1-4.5 cm latus, campanulatus vel plano-convexus, obtuse umbonatus; ad marginem versus et integer; siccus appresso-fibrillosus vel fibrillo-squamatus, ochraceo-brunneus vel umbrinus; contextus 2-5 mm crassus, luteus, sapor pungens vel indistinctus et odor indistinctus. Lamellae 6-9 mm latae, emarginati vel adnexae, confertae demum subdistantes; pallide lutei demum olivaceo-brunnae. Stipes 3-9 (11) cm longus, 2-7 mm crassus, aequalis; ochraceous vel cinnamomeus; basi porphyreus; fibrillosus; contextus firmus excavascens. Sporae (7)8-9 x 5.5-6 μm, ellipticae, verruculosae.

Holotypus ACAD 13265, in sylva, prope lacum Aylesford, comitato Kings, Nova Scotia lectus; in herbario E.C. Smithii, Universitatis Acadiae (ACAD) conservatus.

Basidiocarp: Pileus 1-4.5 cm broad, conic-campanulate, convex to plano-convex, obtuse umbonate; margin incurved to decurved, edge entire, thin, splitting radially when mature; surface more or less dry, velvety, appressed fibrillose to fibrillose-scaly, dark yellowish brown (Yellow Ocher, Old Gold, to Snuff Brown) on the margin, drab grey-brown, dark to dark reddish brown (Sepia, Bister, Chestnut-Brown to Prout's Brown) on the disc, dark brown fibrillose streaks over the pileus; context 0.2-0.5 cm thick, firm, moist, drab whitish buff to very pale yellow (Maize Yellow to Straw Yellow) becoming drab watery; taste raphanoid to indistinctive, odor not distinctive; KOH watery brown to dark brown on pileus surface, on dried material dark reddish brown on pileus and lamellae. Lamellae 0.6-0.9 cm broad, emarginate, adnexed, to seceding, ventricose, close to subdistant, edges even to wavy, at first yellow (Light Cadmium to Deep Chrome) to deep yellow-orange to brownish golden (Primuline Yellow to Aniline Yellow) and becoming rusty with maturity of the spores. Stipe 3-9 (11) x 0.2-0.7 cm, equal, or broader at the base; apex satiny yellow-orange-tinted to light yellow (Empire Yellow to Mustard Yellow), ground color similar, becoming dull to brownish at the base, overlaid with scattered to contiguous red-brown to dark brown (Cinnamon, Snuff Brown to Dresden Brown) fibrils; base dull reddish rusty brown (Tawny, Rufous), fibrils and base becoming dark or sordid from handling and age; context firm, stuffed, hollowing from base to apex, becoming watery when mature, at first dull yellowish orange (Empire Yellow, Light Orange-Yellow) to drab ochraceous (Buff-Yellow) or reddish-tinted with age, base cortex olivaceous, drab watery, often reddish-tinted; cortina pale yellow.

Microscopic Features: Spores (7)8-9 x 5-6 μm, in adaxial view long-ovate or elliptic, verruculose, in KOH hyaline to light golden yellow or golden brownish, often having a guttala; under the SEM, long-ovate or elliptic, ornamentation very close, of small irregular warts, variable in size, fused in many places into complex patterns; apiculus not visible. Basidia 25-30 x 6-7 μm, 4-spored, clavate to broadly clavate, in KOH hyaline, yellow or brownish-pigmented, often containing colorless refractive particles and droplets; basidioles 15-26 x 6-7.2 μm, clavate, similar to the basidia. Subhymenial hyphae compactly interwoven, of tubular to inflated cells, 2.2-4.4 μm wide, in KOH hyaline, in Melzer's yellowish; tramal hyphae subparallel to interwoven, cells inflated, tubular, 5.5-13 μm wide, walls 0.5-1.1 μm, in KOH hyaline to light yellowish, in Melzer's yellowish. Surface hyphae of pileus interwoven, cells tubular, slightly inflated, 5-13 (18) μm wide, walls 0.5-1.1 μm, in KOH hyaline to light brownish, in Melzer's dull yellow to light brownish; tramal hyphae interwoven, cells tubular, inflated, 5-14 μm wide, walls 0.5-1.1 μm, in KOH hyaline to pale yellowish, having yellow-pigmented areas, in Melzer's hyaline to yellowish. Cortical hyphae of stipe parallel to subparallel, cells tubular to inflated, 2.5-14.5 μm wide, in KOH hyaline, pale yellowish, to light brownish, in Melzer's hyaline to yellowish, often having colorless or yellowish particles on the cell walls; basal hyphae irregularly interwoven, branched, cells tubular, 2.5-4 μm wide, in KOH hyaline to light yellowish, occasionally having orange pigments. Universal veil hyphae tubular, branched 2.5-10.5 μm wide, thin-walled, in KOH hyaline to dull yellowish, often containing minute colorless granules. Oleiferous hyphae present in the pileus, lamellar trama, stipe cortex and basal mycelium. Interhyphal pigment deposits present in the pileus, lamellar trama and stipe cortex; in KOH yellow, golden, red-orange and brownish, soon disappearing, in H_2O yellow-golden, greenish yellow (olivaceous) brownish, and red-brownish, in Melzer's yellow, golden yellow and orange-red.

Habit and Habitat: Single, scattered to gregarious, in *Sphagnum* spp. and other mosses, under conifers and in mixed woods. September to October.

Material Examined: 13263, 13/9/79, Aylesford Lake Road, Kings Co.; 13264, 16/9/79, Aylesford Lake Road, Kings Co.; 13265* and 13266, 18/9/79, Division Road, Pictou, Pictou Co.; 13267, 5/10/79, Aldershot, Kings Co.

Observations: C. pseudotubarius belongs in the stirps Tubarius (Ammirati 1972), and differs from *C. tubarius* in the dark olivaceous colors of the latter, and from *C. tubarius* var. *luteofolius* in that the stipe of *pseudotubarius* is reddish at the base and bright yellowish overall.

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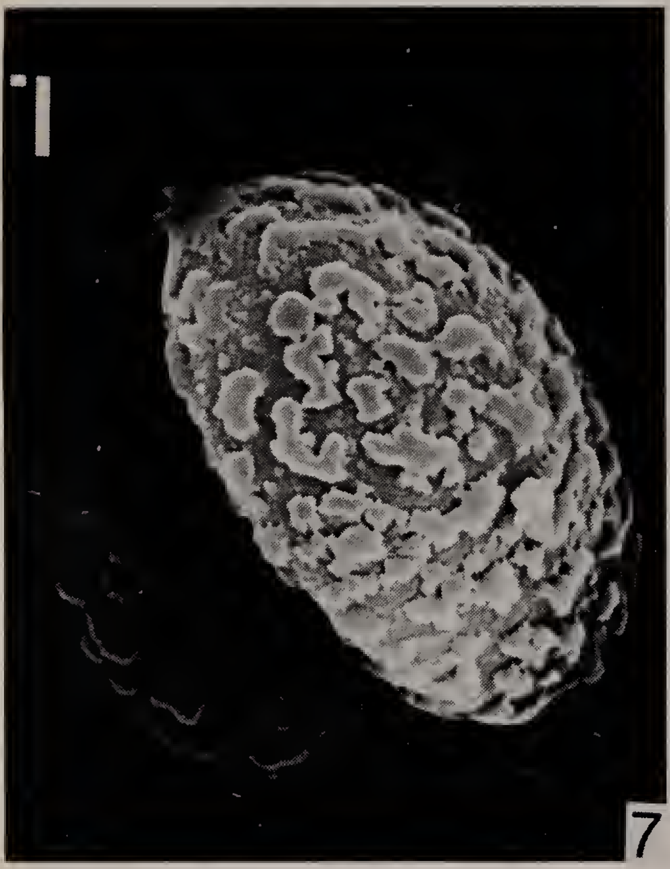
Fig 1. *Cortinarius huronensis* var. *huronensis*. Scale bar = 1 cm.
Fig 2. *Cortinarius malicorius*. Scale bar = 1 cm.

Fig 3. *Cortinarius rubeus.* Scale bar = 1 cm.
Fig 4. *Cortinarius semisanguineus.* Scale bar = 1 cm.

Fig 5. *Cortinarius cinnamomeoluteus*. Scale bar = 1 cm.
Fig 6. *Cortinarius pseudotubarius*. Scale bar = 1 cm.



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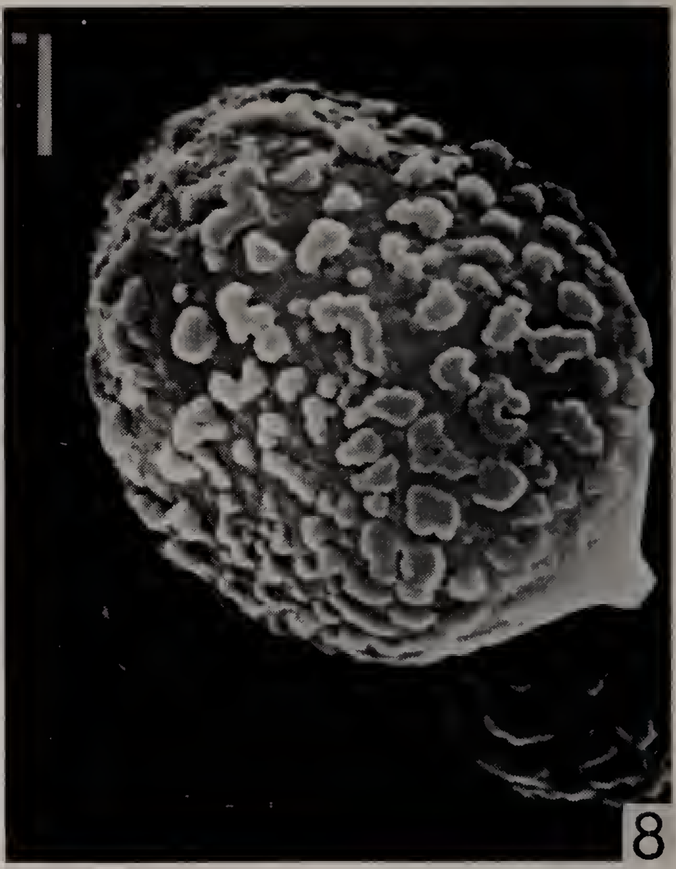

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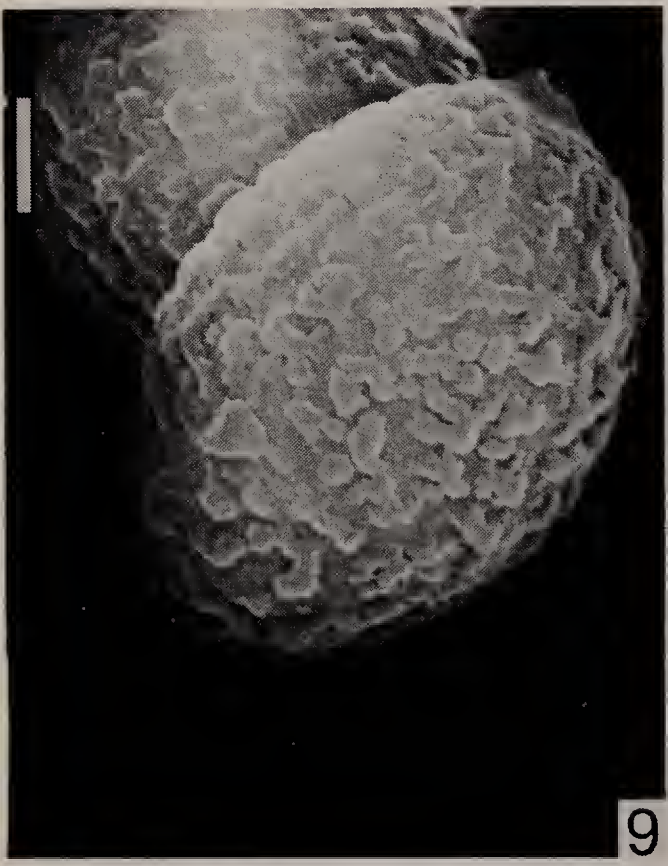

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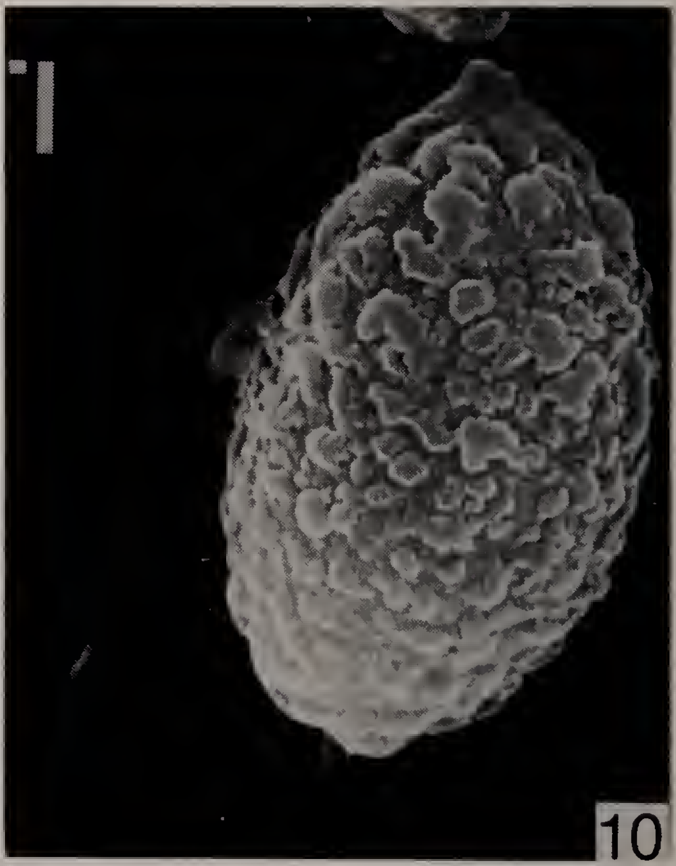

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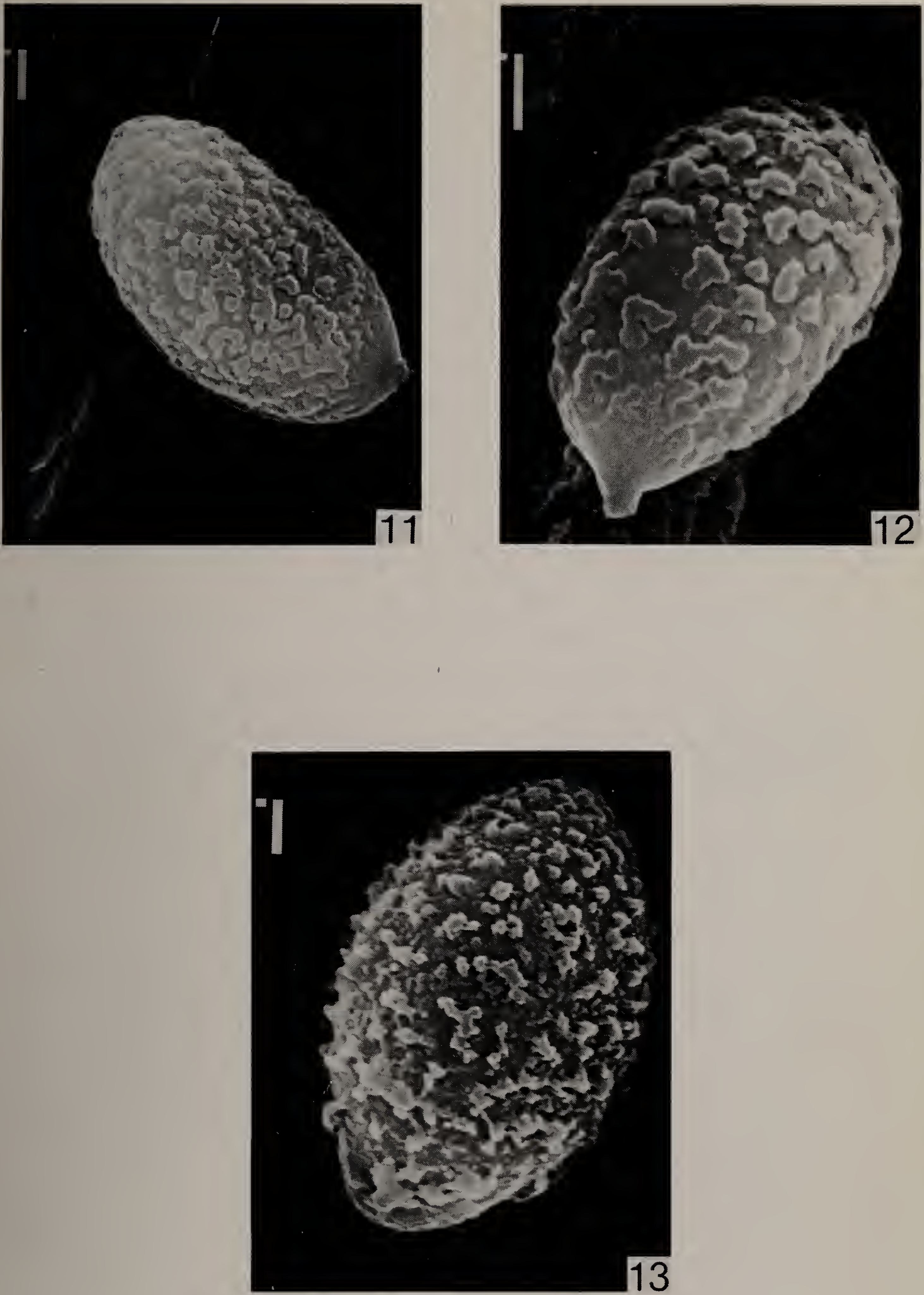
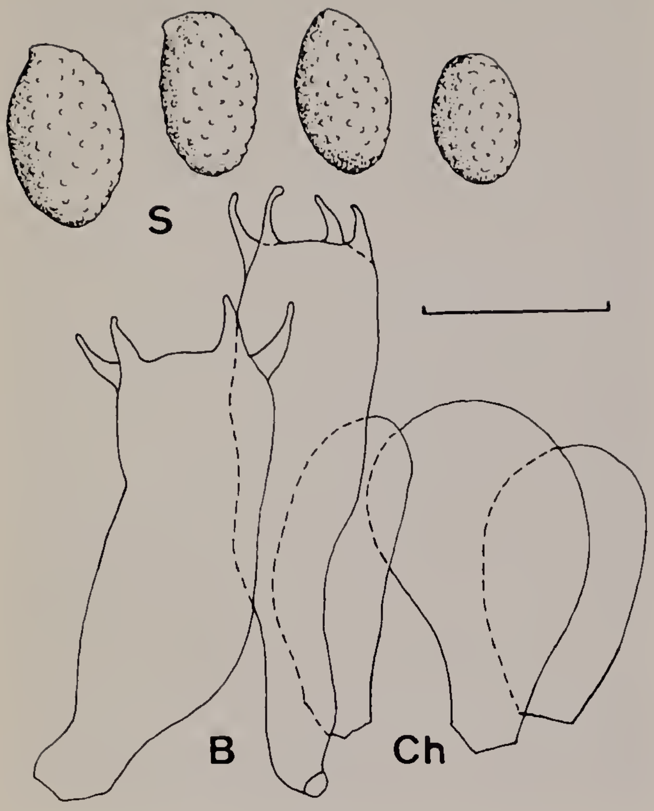
Figs 7-10. Scanning electron micrographs of *Cortinarius* spores. Scale bars = 1 μm. Fig 7. *C. huronensis* var. *huronensis*. Fig 8. *C. malicorius*. Fig 9. *C. rubeus*. Fig 10. *C. sanguineus*.



Figs 11-13. Scanning electron micrographs of *Cortinarius* spores. Scale bars = 1 μm. Fig 11. *C. semisanguineus.* Fig 12. *C. cinnamomeoluteus.* Fig 13. *C. pseudotubarius.*



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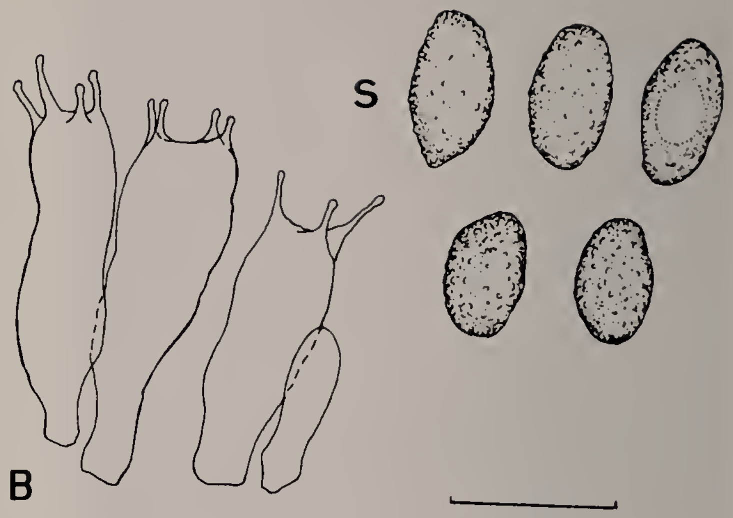

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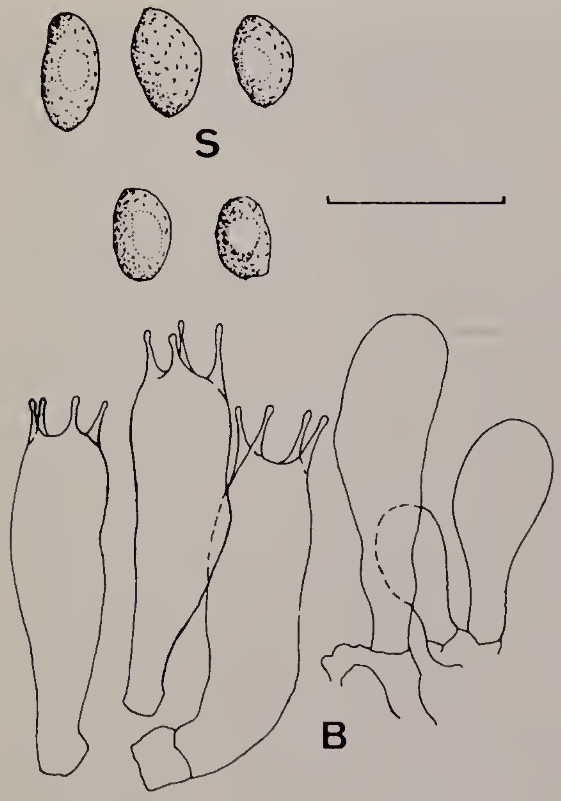

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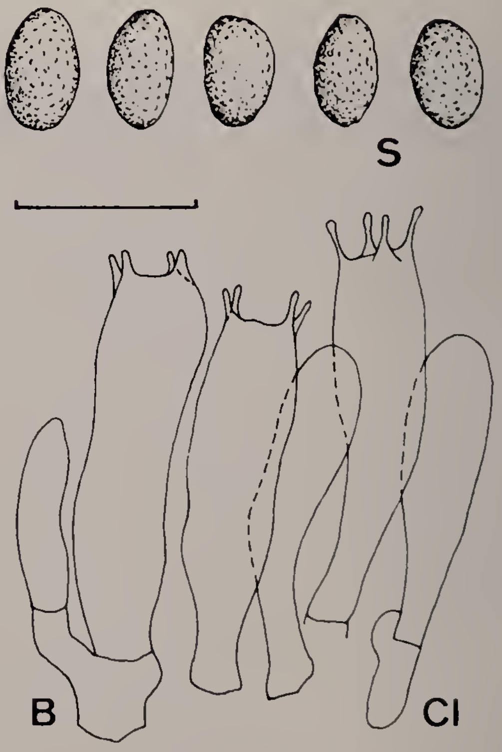

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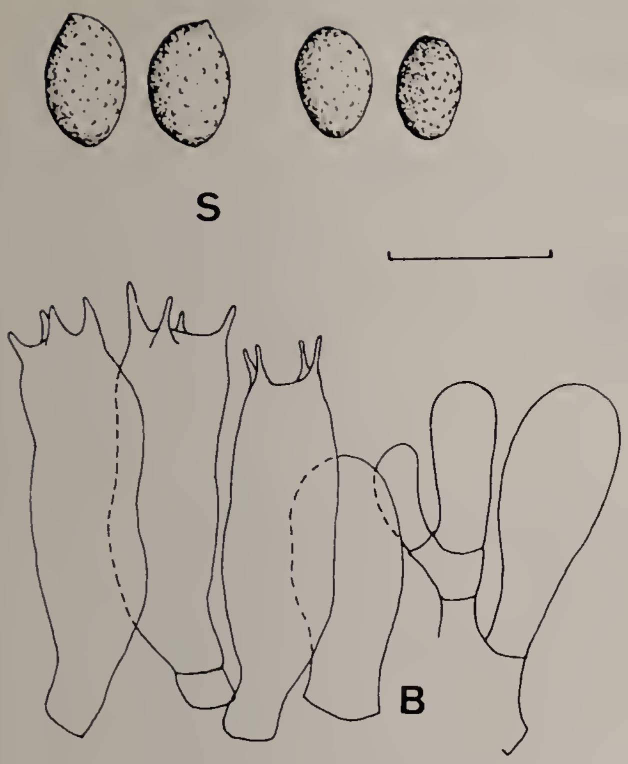
Figs 14-17. Basidia (B) and spores (S) of *Cortinarius*. Scale bars = 10 μm. Fig 14. *C. huronensis* var. *huronensis*. Ch. = cheilocystidia. Fig 15. *C. incognitus*. Fig 16. *C. malicorius*. Fig 17. *C. rubeus*. Cl = clamp.



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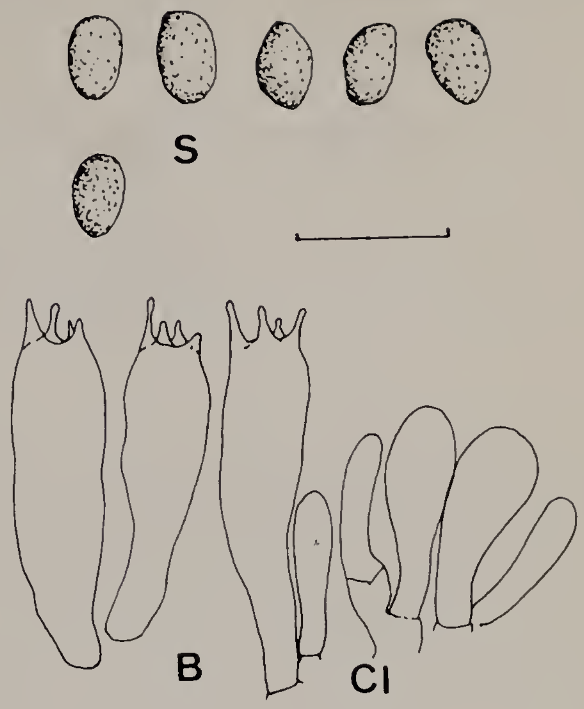

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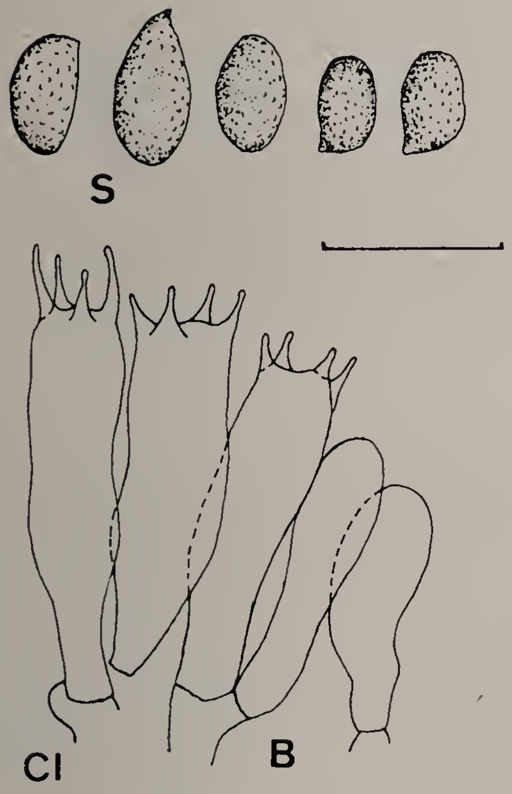

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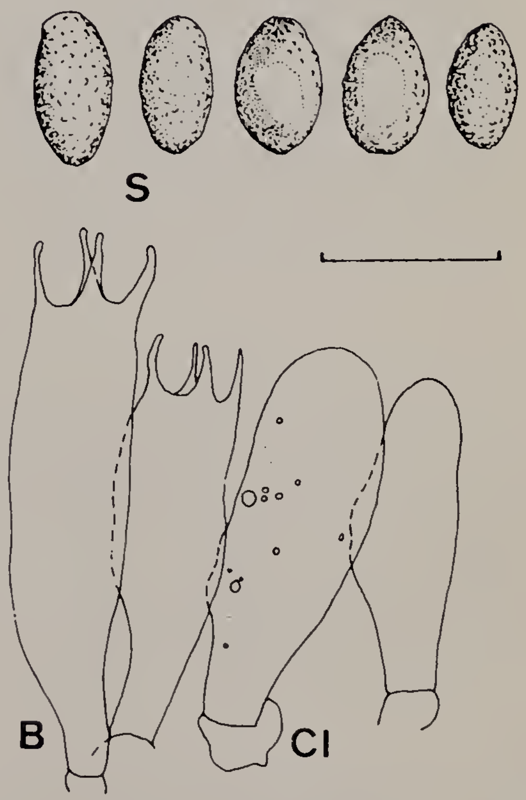

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Figs 18-21. Basidia (B) and spores (S) of *Cortinarius*. Cl = clamp. Scale bars = 10 µm. Fig 18. *C. sanguineus*. Fig 19. *C. semisanguineus*. Fig 20. *C. cinnamomeoluteus*. Fig 21. *C. pseudotubarius*.

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FOOD OF SOME IMMATURE FISH OF MINAS BASIN, BAY OF FUNDY

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Stomach contents of juveniles of 11 species of fish collected in the southern bight of Minas Basin were examined. Most species, including typically planktivorous ones such as smelt *(Osmerus mordax)* and silversides *(Menidia menidia)*, exhibited broad food spectra having both planktonic (copepods and meroplankton) and benthic (amphipods, isopods, cumaceans, and sedentary polychaetes) components. Only the blackspotted stickleback *(Gasterosteus wheatlandi)* was primarily planktivorous. The amphipod *Corophium volutator* appears to be a major food item for many juvenile fish in this region of Minas Basin. At times saltmarsh insects were also of considerable importance. The lack of feeding specialization may result from the extensive tidal fluctuations that stir up organisms from the benthos and wash out arthropods from nearby salt-marshes.

Les jeunes de 11 espèces de poissons, récoltés dans la boucle sud du Bassin de Minas, ont eu leur contenu stomacal examiné. La plupart des espèces, y compris des poissons plactonivores type tels que l'éperlan *(Osmerus mordax)* et la capucette *Menidia menidia)*, ont une gamme alimentaire étendue, d'origine planctonique (Copépodes et méroplancton) et benthique (amphipodes, isopodes, cumacées et polychètes sédentaires). Seule l'épinoche tachetée *(Gasterosteus wheatlandi)* est essentiellement planctonivore. L'amphipode *Corophium volutator* semble être un aliment d'importance pour plusieurs poissons juvéniles de cette région du Bassin de Minas. Par moments, les insectes des marais salants ont aussi une importance considérable. Ce manque de spécialisation dans l'alimentation pourrait être le résultat des énormes marées qui soulèvent dans la colonne d'eau les organismes benthiques et y entraînent les arthropodes des marais salants avoisinants.

Introduction

The Minas Basin is a large (805 km^2) turbid embayment at the head of the Bay of Fundy noted for having the world's highest recorded tidal range (<16 m). Since 1976, the possibility of tidal power development has focused considerable attention on the area. Although the Basin has a very low production of adult fish (Huntsman 1952), it has been suggested that the region might be an important nursery for several commercially valuable fish, including the herring *(Clupea harengus)*, alewife (*Alosa pseudoharengus*), and shad *(A. sapidissima)* (Daborn & Bleakney 1977).

The present study represents the first attempt to define feeding relationships for juvenile fish in the inner regions of the Bay of Fundy, and is part of a larger coordinated investigation of the plankton (Pennachetti 1978; Daborn & Pennachetti 1979a; b; Strong 1979), benthos (Gratto 1978; McCurdy 1979; Strong 1978; Strong & Daborn 1979a; b) and shorebird (Boates 1978; Boates & Smith 1979) associations of Minas Basin.

Methods

Immature fish were collected from Kingsport (45°09′N 64°22′W) between June and September 1978 using 15-m and 30-m beach seines with 6.2-mm square mesh. Fish were preserved in 5% neutral formalin and caudal length (from lip to final caudal flexure—CL) was recorded for each individual dissected. The gut was removed and contents gently expressed with a dissecting needle. The gut was then cut open and examined microscopically for remaining contents or parasites. Following identification of macroscopic items, the contents were spread on microscope slides, mounted in polyvinyl alcohol (PVA) stained with lignin pink, and examined at 100X magnification.

Results and Discussion

Juveniles of 11 species were collected and examined. Only 4 of these, the smooth flounder *(Liopsetta putnami),* Atlantic silverside *(Menidia menidia),* American smelt *(Osmerus mordax),* and blackspotted stickleback *(Gasterosteus wheatlandi)* were collected in sufficient numbers for quantitative examination. Results are given in Figure 1.

Juvenile smooth flounder (6.6-74.7 mm CL, year class 0—92% year class 1—8%) fed largely upon harpacticoid copepods and the local mysid *Neomysis americana.* Twenty percent of the individuals examined also had faecal pellets in the anterior part of the gut. However, the presence of the calanoid *Eurytemora herdmani,* saltmarsh insects, and meroplanktonic forms such as trochophores suggests that at times juvenile flounder feed in the water column.

Eurytemora herdmani, pelagic eggs and embryos were the predominant items taken by yearling smelt (25-50 mm CL) whereas larger (second-year) smelts (65-105 mm CL) had consumed large numbers of saltmarsh insects also. Benthic organisms such as harpacticoid copepods, mysids, cumaceans and *Corophium volutator* were present in some specimens of both year classes.

The silverside population was dominated by 1-year-old fish, ranging in size from 50 to 75 mm. A single second-year fish was 82 mm long. All 40 silversides examined had been feeding on the benthic amphipod *Corophium volutator* and 16 of these had also consumed saltmarsh and terrestrial insects. In these fish, insect biomass probably exceeded the total biomass of all other food items including *Corophium.*

By contrast with the above, the blackspotted stickleback (10-40 mm; 0—95%, 1—5%) appeared to feed almost exclusively on planktonic organisms, notably *E. herdmani* and meroplanktonic larvae or embryos. The blackspotted stickleback and the seasnail *(Liparis atlanticus)* were the only species recorded that, as juveniles, had ingested diatoms, in both species the large, planktonic *Coscinodiscus. Cosinodiscus,* however, was the major food item encountered in larval *Alosa,* whereas the juvenile captured (55 mm CL) had been feeding on *Neomysis americana* (Imrie 1979).

The remaining fish encountered included the little skate *(Raja erinacea),* tomcod *(Microgadus tomcod),* white hake *(Urophycis tenuis),* and longhorn sculpin *(Myoxocephalus octodecemspinosus).* All had been feeding on a broad spectrum of food that included amphipods, nematodes, isopods, euphausids, polychaetes, copepods, and mysids. In terms of biomass the benthic component was always dominant. None of these latter species apparently utilized terrestrial or saltmarsh arthropods.

Little indication of feeding specialization is thus evident in these results. Except for the blackspotted stickleback, a few specimens of which were examined, most species appear to feed on a great variety of food including organisms both of the benthos and plankton. This is particularly surprising in the case of the silverside, that has a decidedly oblique mouth which would seem to preclude feeding on the bottom. Yet, as noted, all specimens had ingested *Corophium,* presumably when these amphipods were in the water column. Their presence

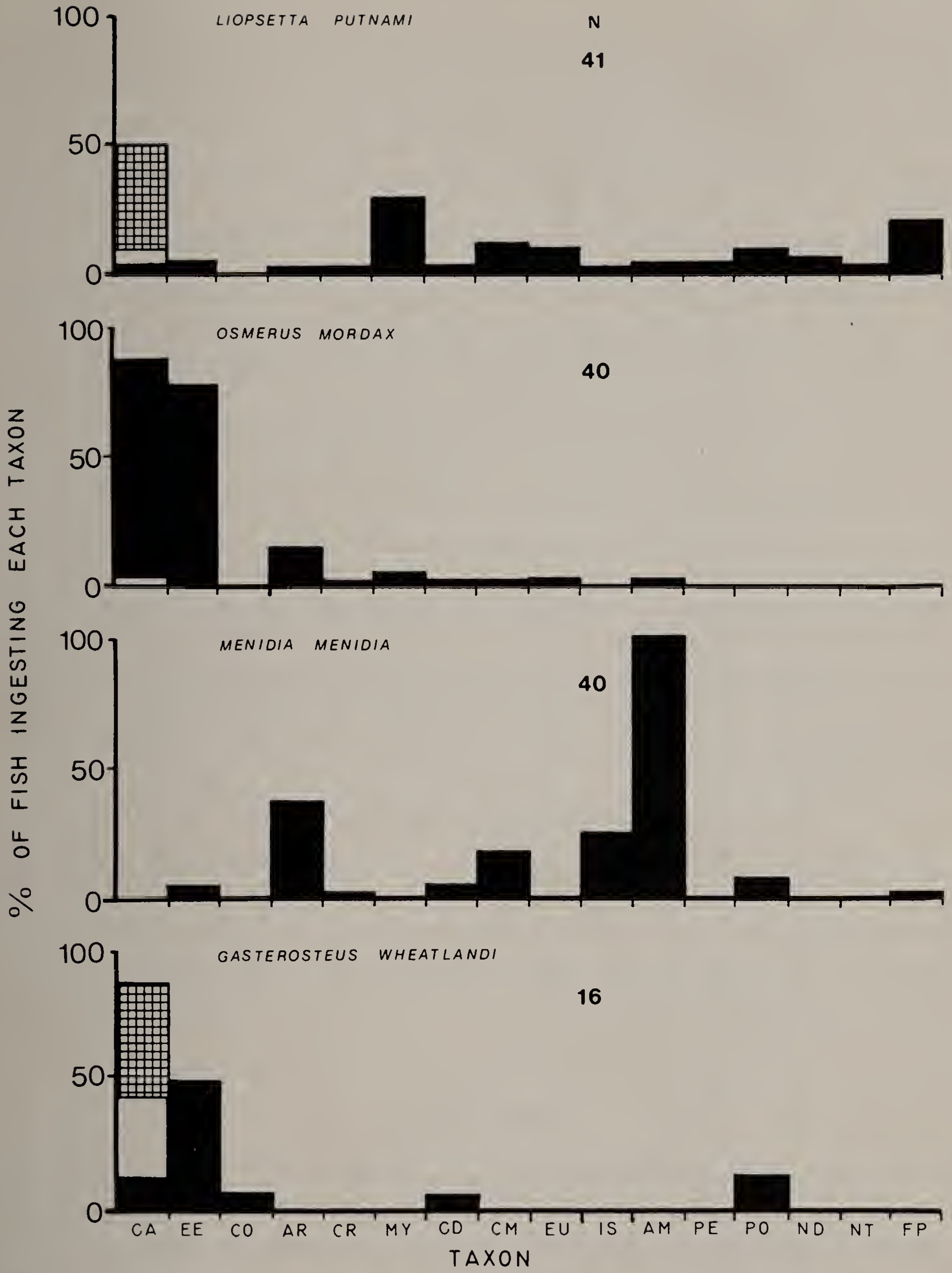

Fig 1. Food spectra of juvenile fish from the southern bight of Minas Basin.

Symbols: CA—Copepoda, including Harpacticoida (cross-hatched), *Eurytemora herdmani* (shaded) and juvenile or unidentified copepods (unshaded); EE—pelagic eggs or embryos; CO—*Coscinodiscus spp;* AR—saltmarsh arthropods; CR—unidentified Crustacea (fragments); MY—*Neomysis americana* (Mysidacea); CD—Caridea; CM—Cumacea; EU—Euphausiacea; IS—Isopoda; AM—Amphipoda (usually *Corophium volutator*); PE—Pelecypoda; PO—Polychaeta; ND—Nematoda; NT—Nemertinea; FP—faecal pellets.
N = No. fish examined.

above the bottom might be the result of either periodic but infrequent swimming behavior for which *Corophium* is noted (Watkin 1941; Perkins 1974), or tidal disturbance during the flooding tide. It should be noted, however, that *Menidia* also had a number of other benthic components in the gut including the isopod *Chiridotea,* cumaceans, and faecal pellets.

These results also suggest a significant role for saltmarsh arthropods in the nutrition of fish in southern Minas Basin. The collection area is near the extensive Kingsport saltmarsh which, in 1978 at least, supported large numbers of insects, notably delphacids, cicadellids, and ants (Krepinsky, in. verb.) As Cheng and Birch (1978) have suggested, insect "flotsam" is a potentially rich source of food for surface-feeding marine organisms, and one that is frequently overlooked.

Our evidence fails to confirm the proposition that the region is an important nursery area for commercially valuable fish. Except for the alewife and flounder, those species captured are probably best described as forage fish, being potential food for much larger piscivorous species. Obviously, the very restrictive nature of our collecting methods and locality limits the conclusions that can be drawn regarding the role of the Minas Basin in supporting distant fisheries through a nursery function. Nonetheless, the extent of utilization of saltmarsh insects and both benthic and planktonic organisms in the southern bight suggests that the productive local saltmarshes are important for the support of some resident and transient members of the ichthyofauna. The role of tidal movements would also seem to be clear, as high-tide flushing of saltmarshes and flood-tide disturbance of deposited sediments seem to be important mechanisms making these food sources available to fish that otherwise might be unable to use them for morphological reasons.

Acknowledgements

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AN ANALYSIS OF SOME BIOLOGICAL CHARACTERISTICS OF THE 4X JUVENILE-HERRING FISHERY

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An analysis of some biological characteristics of juvenile herring from the Bay of Fundy area revealed significant changes in growth and in length at age, and at maturity in the early 1970's. A corresponding shift in the relationship between growth and abundance of juvenile herring, from density dependence to lack of density dependence, is also demonstrated. These events occurred when some of the adult populations adjacent to the Bay of Fundy were in a period of radical decline. An explanation of these phenomena is presented, based on differential reduction in the adult stocks that contribute to the juvenile herring mosaic in the Bay of Fundy.

On se sert d'une analyse de quelques paramètres biologiques du hareng juvénile des environs de la Baie de Fundy pour dévoiler d'importants changements survenus au début des années 1970 en ce qui a trait au taux de croissance, à la taille par âge et la taille à maturité de ces animaux. On démontre aussi qu'au cours de la même période la relation entre la croissance du hareng juvénile et son abondance est devenue indépendante de la densité de population. Ces événements se sont produits alors que quelques unes des populations adultes adjacentes à la Baie de Fundy subissaient un déclin radical. On propose pour ces phénomènes une explication basée sur le concept d'une réduction différentielle des stocks adultes qui contribuent à la mosaïque du hareng juvénile de la Baie de Fundy.

Introduction

The weir fishery for juvenile herring on the New Brunswick side of the Bay of Fundy (NAFO Div. 4Xb, Fig 1), together with the contiguous fishery in Maine, (NAFO Div. 5Y), supplied the oldest fish-processing industry on the North American east coast (Huntsman 1953). More recently, large-scale multinational adult fisheries have developed, which exceeded the juvenile fisheries to a degree that threatened the future of both adult and juvenile populations (ICNAF 1972).

The Canadian herring catch in 4X has been sampled in considerable detail since 1968 for length frequencies and other biological parameters. Prior to 1968, less detailed sampling of the catch was done. The aim of this study is to analyse this data base with particular reference to the juvenile fishery. Analysis of the juvenile-population responses to changes in abundance and to the degree of mixing of separate spawning stocks provides information of a qualitative nature that may be useful in the analytical assessment of the 4WX herring management unit.

The herring fishery off southwest Nova Scotia and in the Bay of Fundy exploits a mixture of stocks (ICNAF 1972). The 3 major stocks spawn respectively off southwest Nova Scotia, in the Gulf of Maine, and on Georges Bank. The spawning areas and associated larval distributions of each stock are unique, but there is

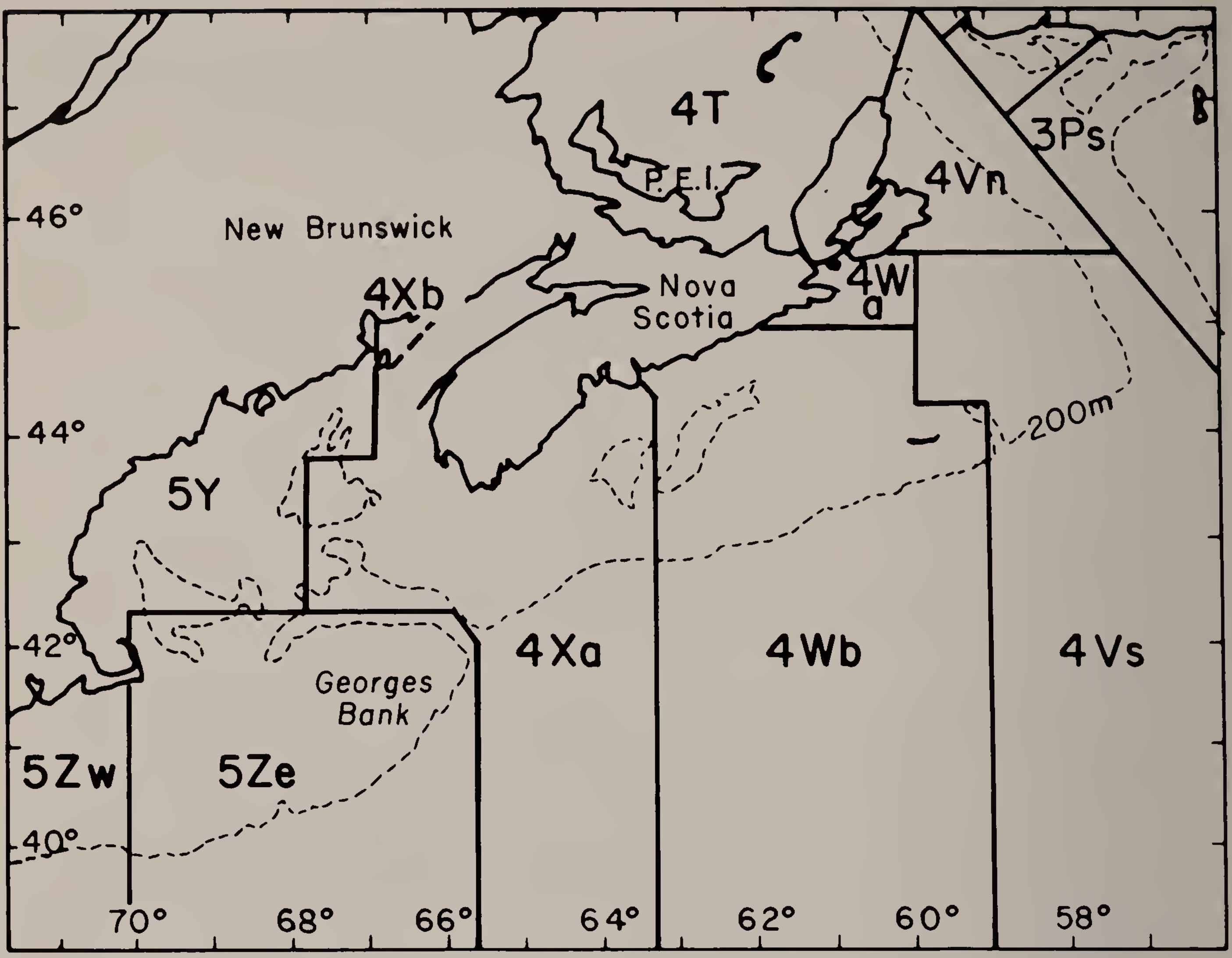

Fig 1. Areas of the 4WX and 5YZ herring fisheries.

mixing, in unknown proportions, of the juveniles (Messieh 1970) and of the adults (Stobo et al. 1975). Specifically, there is mixing of "Gulf of Maine" and "Southwest Nova Scotia" juveniles along the coast of Maine and in the Bay of Fundy. Also there is in direct evidence that juveniles from the Georges Bank stock contributed to catches in the New Brunswick weir fishery in the early 1970's (ICNAF 1973). In addition, there is a much smaller stock of herring that spawns at Grand Manan in 4Xb (Huntsman 1953), whose juveniles are almost certain to be admixed in the Bay of Fundy fishery.

The relative proportions of the 4WX herring catch contributed by the respective spawning stocks and the temporal changes of these proportions are not known. However, it is expected that the growth, maturation and spatial distributions of herring in 4WX have been influenced by both the environment and changes in the relative contributions by each spawning stock.

A review of the historical catches in NAFO SA 4 and 5 indicates the major recent events of the component spawning stocks. The recent 5Y adult and juvenile catches and the 5Z adult catches are shown in Figure 2 (after Sissenwine & Waring 1979). The Georges Bank fishery collapsed because of overfishing in the first half of the 1970's and, based on larval and adult surveys, there is no indication of recovery (Anthony & Waring 1980). The Gulf of Maine adult fishery (5Y adult) has also declined by about 50% since 1972. The 5Y juvenile catch fell to a low in 1972 which preceded the decline in the 5Y and 5Z adult fisheries. Since then the 5Y juvenile catch has been increasing because of an increase in mobile gear effort and the appearance of large 1976 and 1977 year-classes. The catch distribution of juveniles in 4Xb parallels that of coastal Maine but is different from the 4Xa juvenile catch distribution (Nova Scotia side of Bay of Fundy). The 4WX adult catch did not decline dramatically in parallel with adult catches in SA5 (Fig 2), but fell to an all-time low in 1978.

Materials and Methods

Length and Weight

Mean lengths and weights at age for a given month were estimated routinely from catch samples in preparation for the stock assessment. Length-frequency samples were weighted by catch and combined. Monthly age-length keys were constructed and removals at age by 1-cm length intervals were calculated.

Maturity

Mean length at 50% maturity by sex was calculated from the detailed biological samples. A maturity stage-length key was constructed from purse-seiner samples taken in August. During August, the purse-seiner fleet concentrates on pre-spawning and spawning schools. Fish at or above stage 3 (Parrish & Saville 1965) were considered mature. The mean length at 50% maturity was calculated from a linear regression of percent mature against length. Data in 1970 were insufficient to calculate a 50% point. All other correlations were significant ($p < 0.01$).

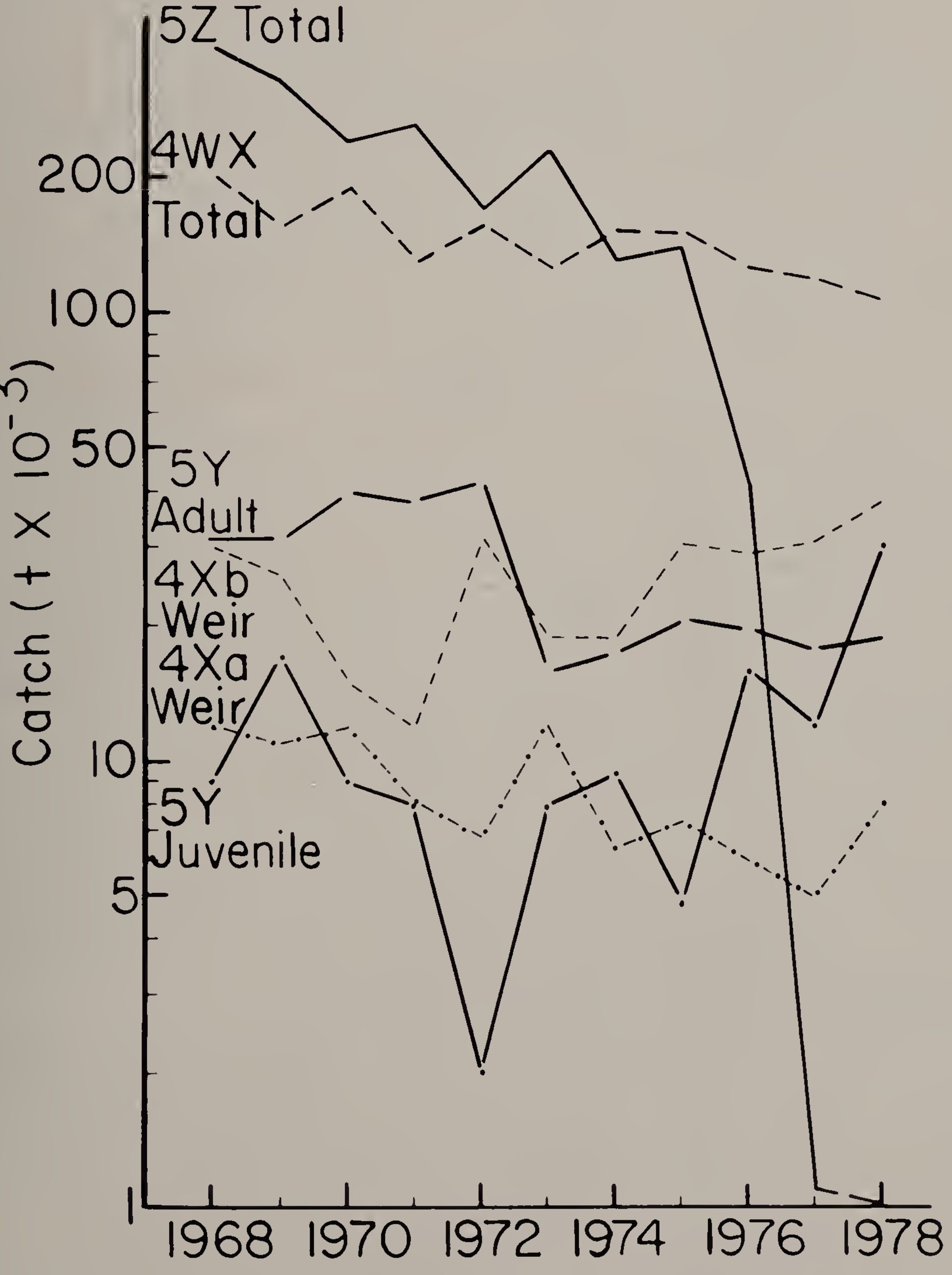

Fig 2. Recent catch histories of the 4WX and 5YZ herring fisheries.

Results

Age Composition

The New Brunswick weir fishery traditionally exploits sardine size herring predominantly at age 2. The monthly age compositions of the catches from 1965 to 1978 are shown in Figure 3. Initially 2- and 3-year-olds make up most of the catches but in the later months 1-year-olds enter the fishery. Large year-classes such as those of 1963, 1966, 1970, and 1976 (Sinclair & Iles 1980) tend to show up earlier in the life history and persist in the fishery longer. It is interesting to note that the 1977 year-class appeared strong in the 1978 catch in spite of the large number of 2-year-olds from the large 1976 year-class. As age 2 fish make up the bulk of the juvenile fishery, this study concentrates on the growth of 2-year-olds.

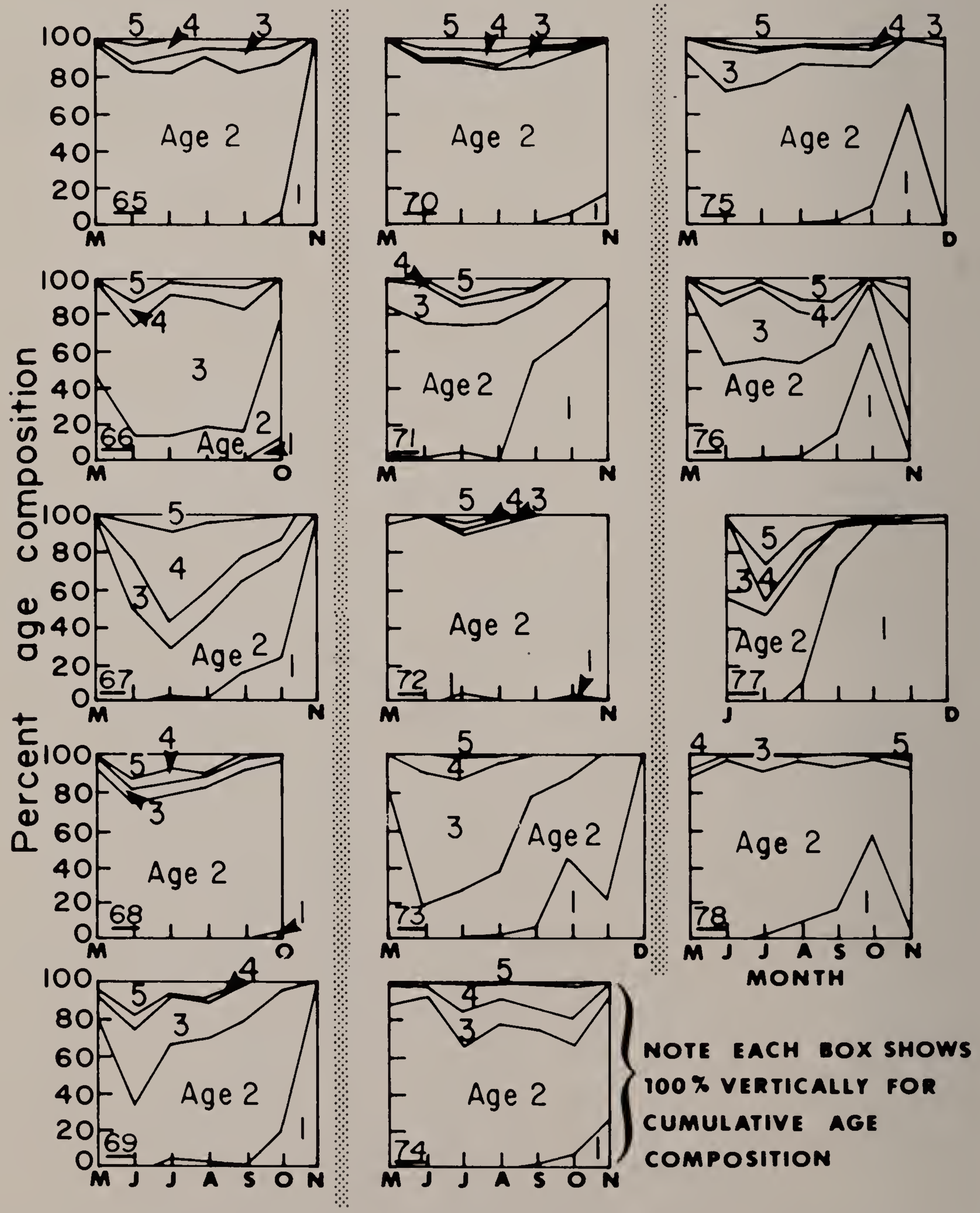

Fig 3. Monthly age composition of the 4Xb weir catches from 1965 to 1978.

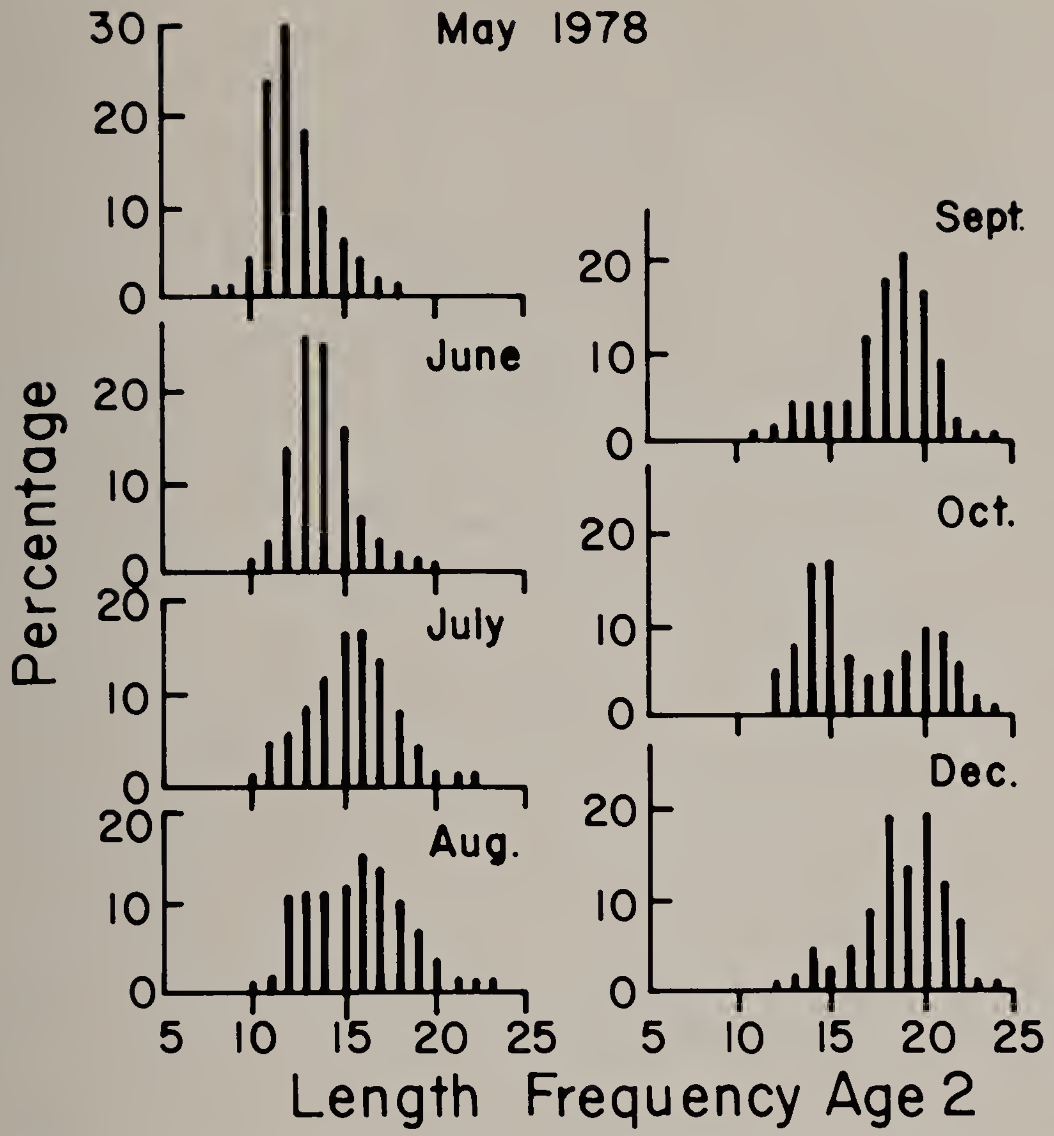

Fig 4. Monthly length frequencies of New Brunswick weir removals, age 2 in 1978.

Growth of 2-year-old Fish

Each year the monthly length frequencies of 2-year-olds were approximately normally distributed during the early part of the fishery but tended to become bimodal by August or September. A representative series of length frequencies (Fig 4) shows a typical seasonal trend. The shift of a single mode from May to July was taken to indicate growth of a unit population. In August, a second mode appears and remains through October. Clearly the mean lengths (to include both modes) calculated from August to October would not be representative of changes in length of a homogenous population. However, the modes on the right-hand side in August and September follow the displacement in the normal distribution from May to July. The growth of only the larger population that was present at the beginning of the season is considered.

A complete time series of length frequencies is available for the months May to September and the calculation of summer growth (length increment) was limited to this time period. However, the major part of the annual growth occurs within these months (Huntsman 1919). Iles (1967) demonstrated that, when length increment is used as a measure of growth, it is essential to correct the increments to the same initial length. When such corrections are not made, as for example by Moores and Winters (1978) and de Veen (1976), erroneous conclusions regarding growth compensation or growth rates may result.

To allow for length-dependent growth, the summer increment was adjusted for initial length, taken as that for May. When length increment was plotted against initial length (Fig 5), 2 temporally distinct groups appeared, which differed in

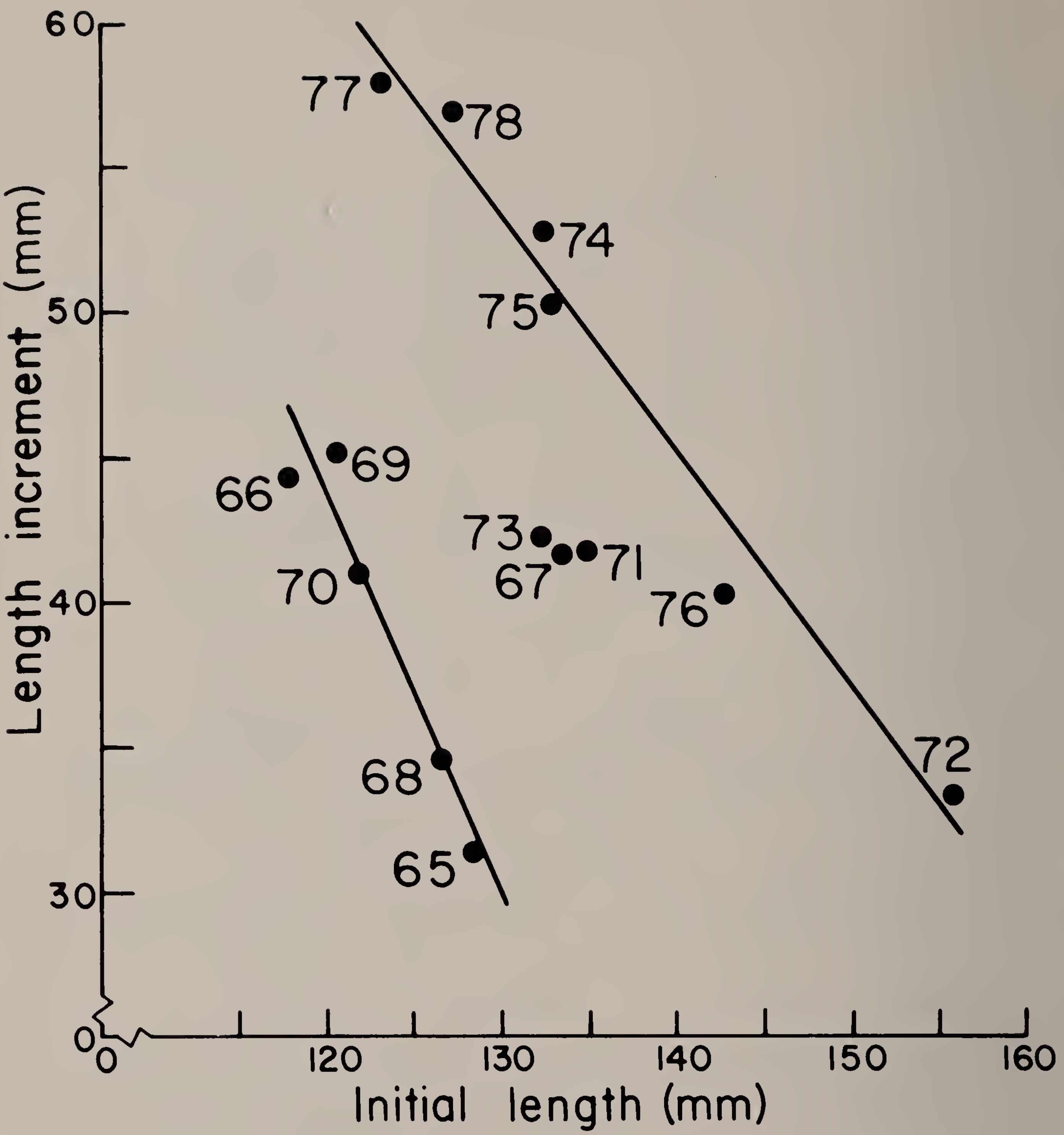

Fig 5. Initial length vs. length increment of age 2 herring from the 4Xb weir fishery.

their growth characteristics. The first group included the years 1965 to 1970, but excluding 1967, and the second the years 1972 and 1974 to 1978. The linear regression of the first group had an r^2 of 0.912 ($p < 0.01$) and of the second group an r^2 of 0.972 ($p < 0.01$). The 1967, 1971, and 1973 points are intermediate between the 2 groups.

A dummy variable (Draper & Smith 1966) was used to account for this apparent discontinuity. The data set was split into 2 groups, the 1967 point being included with the first group and the 1971 and 1973 points with the second group. A multivariate regression gave the equation:

$$\Delta L = 143.0 - 0.7L - 14.7D$$

where ΔL = length increment
L = initial length
D = dummy variable

The length increments were adjusted to a standard initial length of 130 mm using the coefficient of L by:

$$\Delta L' = L - .7(130-L)$$

where $\Delta L'$ = the adjusted length increment

The results of the regression and the length data are presented in Table I.

There is, then, good evidence of a change in the growth characteristics of 4Xb 2-year-old herring in the early 1970's, one that is shown in Figure 6. In the years 1965, 1966, and 1968 to 1970, the adjusted length increments were below 40mm while in the years 1972 and 1974 to 1978 the increments were above 49 mm. Again the 1967, 1971, and 1973 points are intermediate.

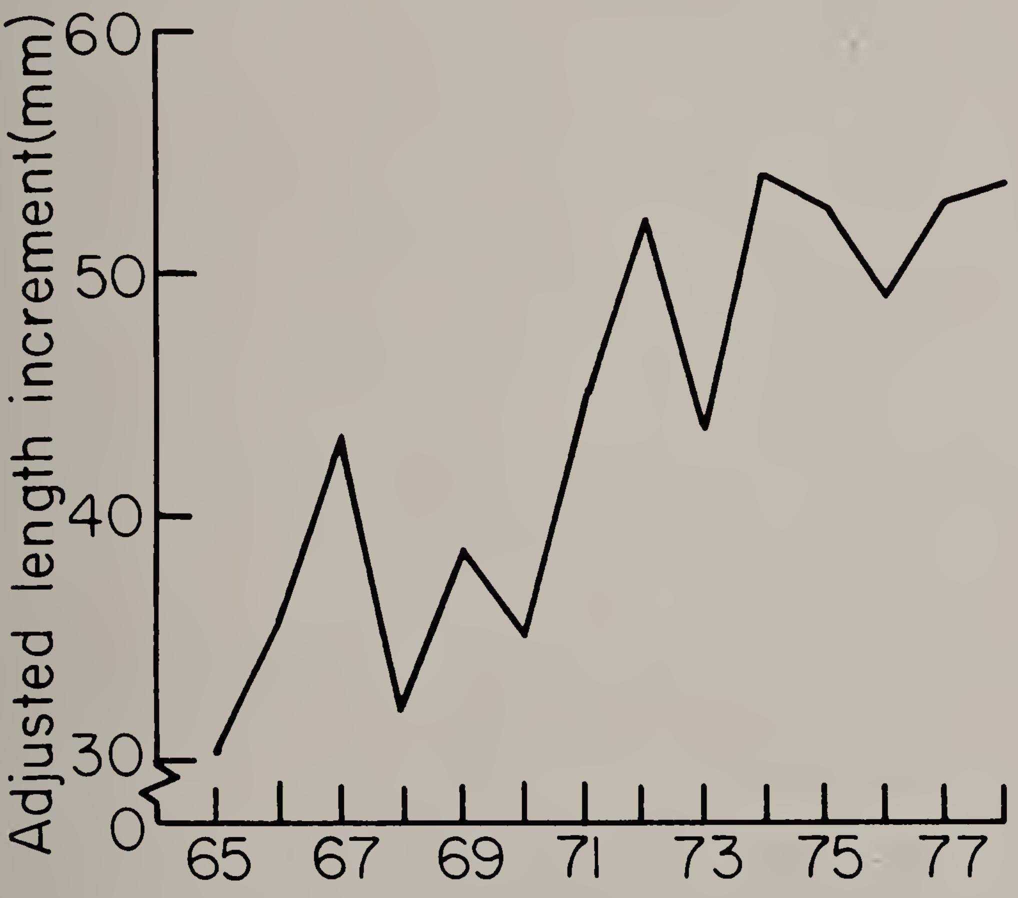

Fig 6. Trend in adjusted length increments of the 4Xb 2-year-olds.

Temperature Effects

Monthly mean-surface temperatures from the St. Andrews Biological Station summed from May to September were plotted against the adjusted length increments to investigate the effect of temperature on growth (Fig 7). The higher summer growth observed during recent years occurred at intermediate temperatures, suggesting that this factor was not the predominant one in the growth changes. However, this is not meant to rule out possible temperature effects on growth.

Effects of Population Abundance

Two estimates of 2-year-old population abundance were calculated for the New Brunswick weir fishery. Because of the uncertain stock identity of the New Brunswick weir catches, it is not necessarily valid to assume that the number of 2-year-olds estimated by cohort analysis for the 4WXa (Nova Scotia) fishery is an appropriate index of the 4Xb (New Brunswick) population size. An alternative measure is the catch per unit effort (CPUE) estimates for the New Brunswick weir

Table I. Initial length and summer length increments of New Brunswick weir age 2 herring.

Year	Initial Length (mm)	Length Increment (mm)	d	Adjusted Length Increment (mm)
1965	128.5	31.5	1	30.4
1966	117.9	44.3	1	35.7
1967	133.6	41.1	1	43.7
1968	126.6	34.6	1	32.2
1969	120.9	45.2	1	38.7
1970	122.0	41.0	1	35.3
1971	134.8	41.7	0	45.1
1972	156.0	33.7	0	52.2
1973	132.2	42.3	0	43.9
1974	132.3	52.7	0	54.3
1975	133.3	50.3	0	52.6
1976	142.8	40.3	0	49.4
1977	123.0	58.0	0	53.0
1978	127.1	56.9	0	54.8

Results of Regression

Variable	Coeff.	SE	*t*-Value
Initial length	-0.7	0.154	-4.60
Dummy	-14.7	2.951	-4.97

Intercept - 143.0

Multiple r^2 - 73.11

fishery. However, CPUE estimates are crude because of scanty information on effort in the weir fishery. In spite of these uncertainties, the 2 measures are considered.

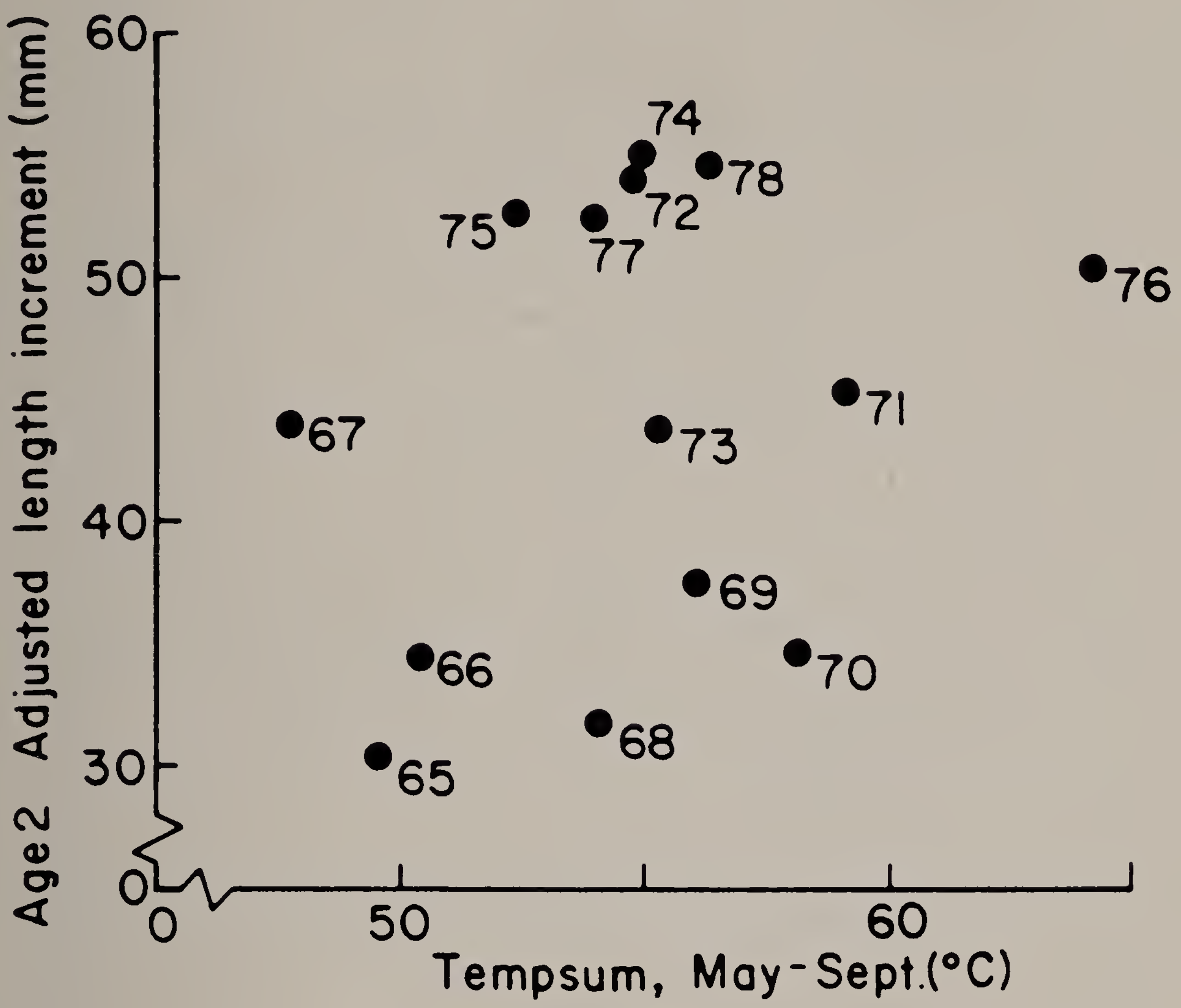

Fig 7. Adjusted 4Xb age 2 length increment vs. monthly mean St. Andrews temperature summed over the growing season.

The catch matrix for the years 1965 to 1978 for the 4WXa fishery (Sinclair et al. 1979) was adjusted to include the autumn-winter juvenile removals by the purse-seiners in 4Xb and one-third of the numbers at age removed by the 4Xb weir fishery.[1] The numbers at age for the 4WX fishery were estimated using cohort analysis (Pope 1972). The estimates of 2-year-olds and the CPUE estimates (catch of 2-year-olds per actively fished weir) are shown in Table II.

In Figures 8 and 9, the adjusted length increments are plotted against the population abundance estimates. Although the position of individual points depends upon the population index that is used, the overall pattern is similar for both indices. The data points fall into 2 groups separated temporally as already shown in Figure 5. The relationship between summer growth and population abundance is inverse during the earlier time period, and perhaps slightly positive in recent years. The temporal separation and the 2 relationships that emerge are independent of year-class size. Each group contains 2 of the largest year-classes recorded in the fisheries (1963, 1966, 1970 & 1976). The 1977 and 1978 population estimates in Figure 9 are from the most recent years of cohort analysis and are thus less precise, but the 1978 point represents a year-class (1976) known to be very large (Fig 3) from other evidence (Sinclair & Iles 1980).

[1] About a third of the long-distance returns of the juveniles tagged in New Brunswick weirs are from 4WXa, the larger proportion being returned from NAFO SA5 (Stobo, in verb.).

Table II. Age 2 population abundance from 4WX and catch per unit of effort estimates for the New Brunswick weir juvenile fishery.

Year	Age 2 Abundance $\times 10^6$	CPUE Index
1965	4526	2.217
1966	2763	.393
1967	2215	.506
1968	4709	1.973
1969	1040	.977
1970	1465	.907
1971	1245	.478
1972	5505	1.718
1973	926	.388
1974	1826	.640
1975	1612	1.204
1976	217	.518
1977	564	.323
1978	5107	1.758

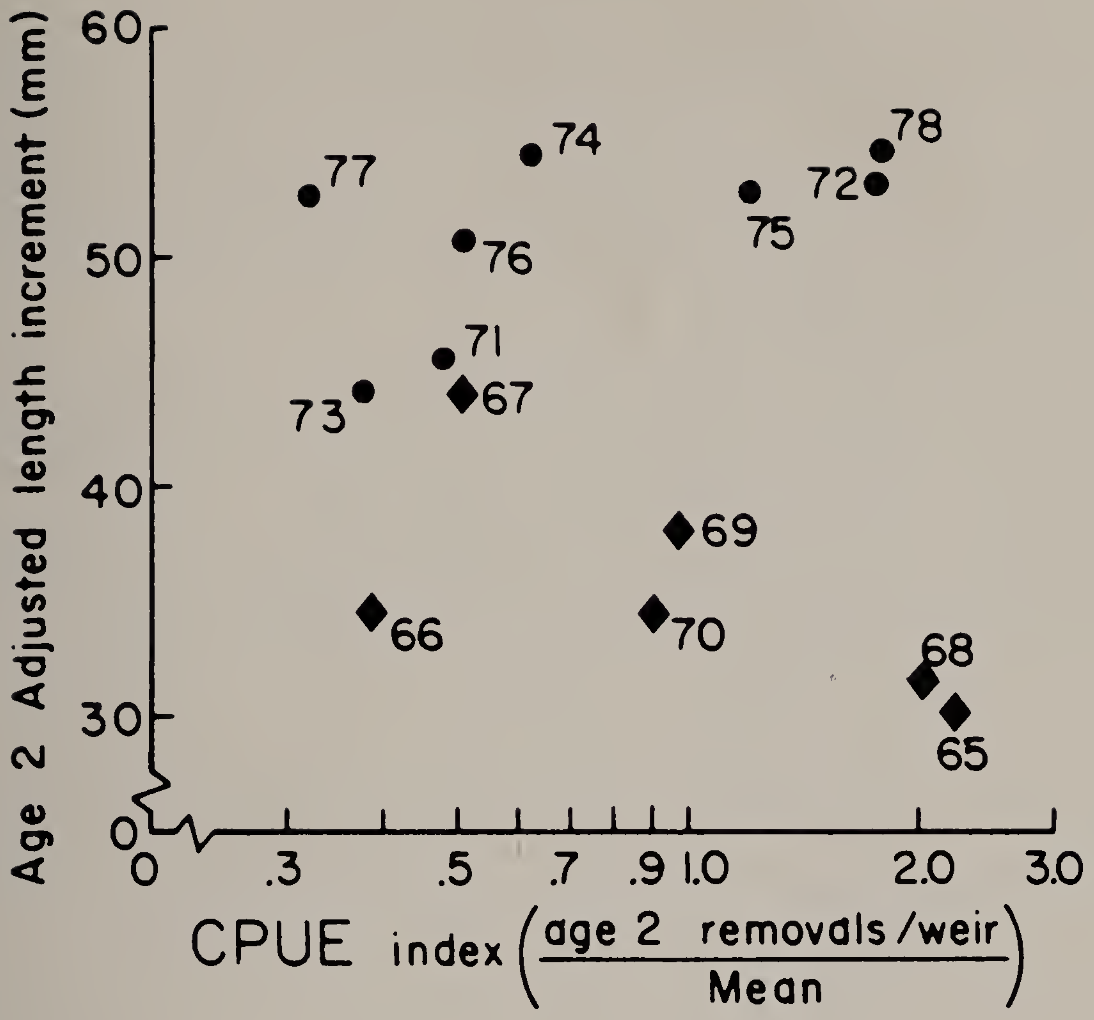

Fig 8. Plot of adjusted length increment of 4Xb 2-year-old herring and CPUE index from 4Xb weirs.

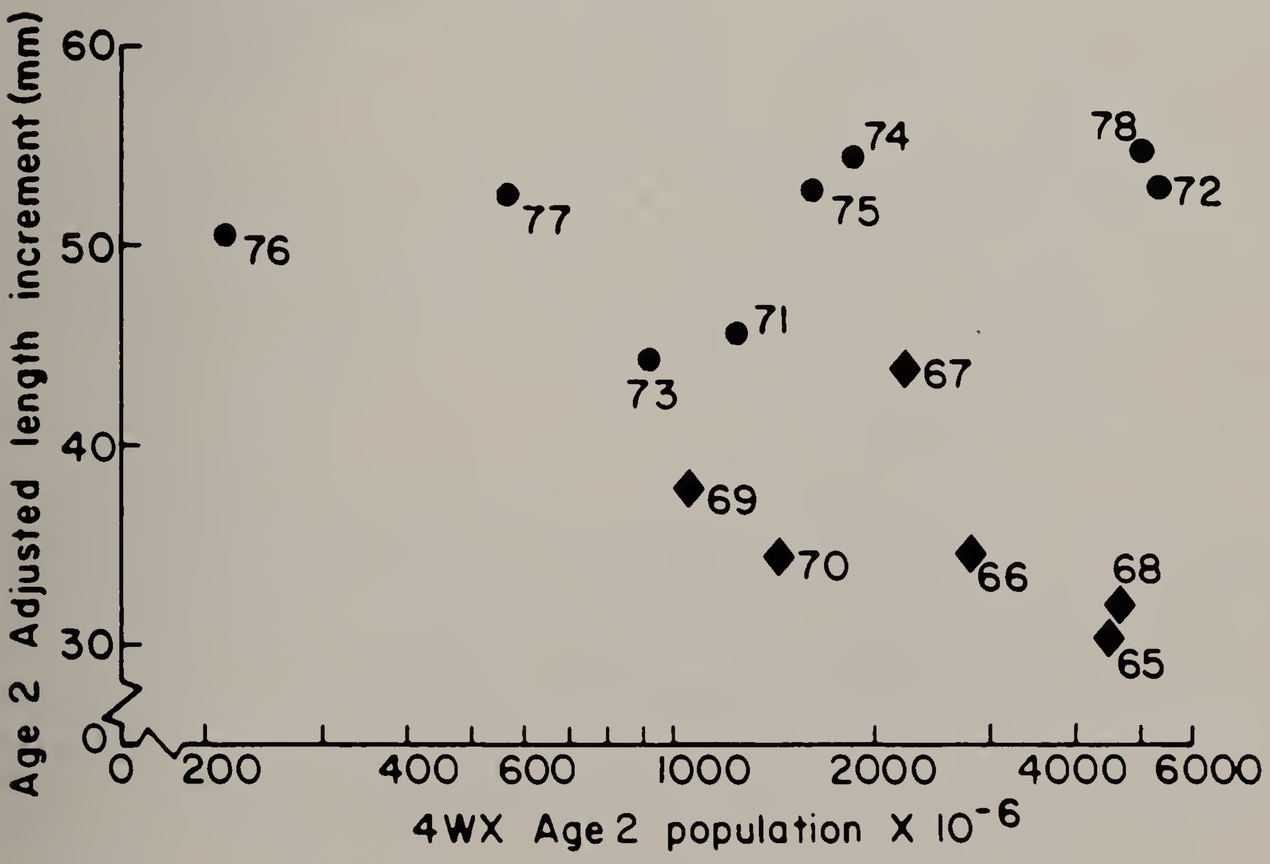

Fig 9. Plot of adjusted length increment of 4Xb 2-year-old herring and age 2 population numbers of the 4WX stock.

The age-2 growth analysis presented here suggests a significant change in the growth pattern of juveniles supporting the New Brunswick weir fishery in the early 1970's. The change included a different relationship between summer-length increment and initial length, an increase in summer growth, and a different response to population abundance from density dependence to lack of density dependence. Direct effects of temperature on growth over the period are not suggested by the data.

Comparisons of Sizes at Age between Fisheries

Fisheries using different gear in different areas and times of year might be expected to exploit different components even of the same year-class and stock. Any systematic difference should then be significant.

In Figure 10 the mean lengths in July for ages 2 and 3 are compared separately and amongst the 3 major fisheries: the New Brunswick weir, the Nova Scotia weir, and the Nova Scotia purse-seine. The frame of reference is the 45° line and the significant features to be explained would be any obvious asymmetry about that line.

At age 2 the mobile gear (the purse-seine) exploits larger fish of the same age than does the fixed gear (the weir). This is shown in Figures 10a and 10b where all points lie on or above the line of reference. Furthermore, prior to 1972 larger individuals were caught in the Nova Scotian weirs than the New Brunswick weirs (Fig 10c), but in recent years the mean lengths have been more comparable. The temporal trend in the ratio of lengths of Nova Scotian age-2 to New Brunswick age-2 herring caught in weirs is shown in Figure 11. The New Brunswick fish have become relatively larger in the years since 1971, about the time when the change in growth pattern was noted.

At age 3 the mobile gear again exploits larger fish and it appears that the lower limit of mean length of recruitment to the mobile fishery is around 242 mm (Fig 10d and 10e). The lengths of weir fish at age 3 range from 200 to 265 mm, whereas all of the purse-seiner lengths except for 1968 are over 242 mm. In the weir fisheries (Fig 10f), the respective mean lengths at age 3 lie closer to the 45° line than at age 2, suggesting that the segregation between the 2 sides of the Bay of Fundy that was shown at age 2 no longer exists at age 3.

It is a well-established characteristic of herring biology that distribution, migration, and recruitment to the adult population are to a significant degree length-dependent. This can lead to a segregation of larger and smaller individuals within a year-class, which is reflected by the exploitation of the different components by different gear. It is very likely that this occurs between the purse-seine and weir fisheries in the Bay of Fundy.

Maturation

Length at 50% maturity for both males and females has fluctuated over a considerable range since 1969 (the first year for which adequate maturity staging was done; Fig 12). As was observed in the growth analysis of the juveniles, there appears to be a marked change in maturation in the early 1970's, a shift towards maturation at smaller lengths (starting with the recruitment of the 1970 year-class).

In summary, the following changes in the biological characteristics of the Bay of Fundy juvenile herring population occurred in the early 1970's:

(i) There occurred a change in the relationship (both intercept and slope) between age 2 summer-length increment and initial length of the New Brunswick weir population.

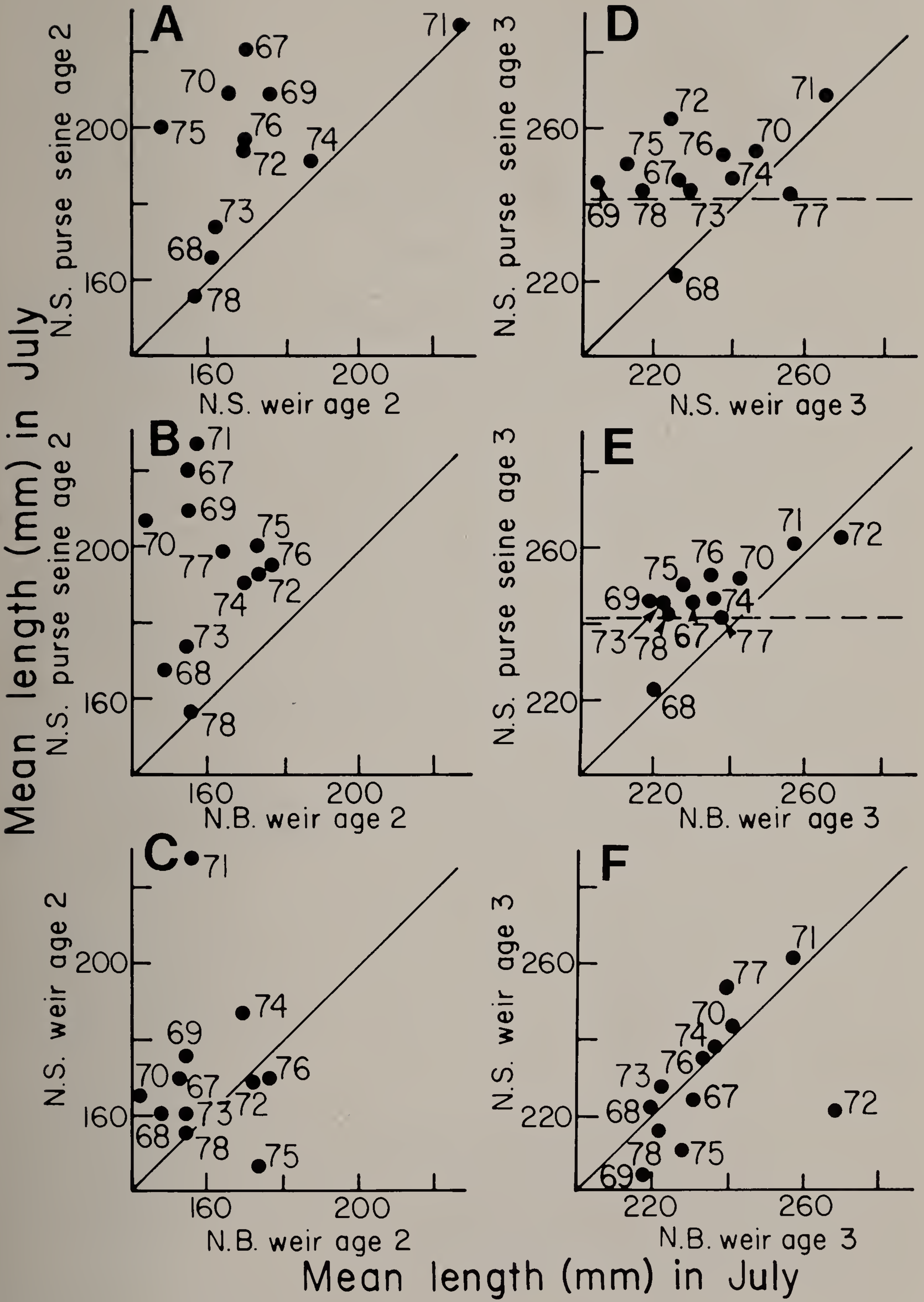

Fig 10. Comparison of mean July lengths of ages 2 and 3 herring caught in the New Brunswick weir, Nova Scotia weir, and Nova Scotia purse-seine fisheries.

(ii) There was an increase in the relative size of New Brunswick weir 2-year-olds. A similar increase in size of Gulf of Maine juveniles was reported by Anthony and Waring (1977).

(iii) The relationship between juvenile summer growth and population abundance changed from density dependence to lack of density dependence.

(iv) length at 50% maturity decreased for both females and males in conjunction with a decrease in stock biomass.

Discussion

Fisheries may be looked upon as major perturbing agents whose biological effects can be studied experimentally using sophisticated fisheries statistics and sampling as a major data source. In recent years, changes in fishing patterns in the study area have occurred to a degree that probably has affected population sizes far more than natural events. The spawning population on Georges Bank over the period 1966 to 1976 declined from 1.5 million t to less than 150 thousand t, and smaller but similar declines were reported for the Gulf of Maine (Anthony 1972; ICNAF 1974). In the 1960's a very large purse-seiner fishery for juveniles in the Bay of Fundy developed, and subsequently was reduced drastically by management controls in the early 1970's (Miller & Iles 1975).

The information presented here demonstrates that there have been biological changes occurring in the New Brunswick weir fisheries that are temporally associated with the fishery changes and are thus likely biological consequences of differential reduction of individual stock components.

The most likely explanation is that reduction of parent stock results in "recruitment overfishing" and a subsequent decline of the overfished stock at the juvenile stage in the traditional nursery grounds. The decline in abundance of juveniles would precede a "crash" in the adult fishery. In the New Brunswick weir fishery area, a major production area for young herring (Huntsman 1953; Iles 1975; 1979), there is the real possibility that an ecological gap resulted from recruitment failure associated with the Georges Bank and Gulf of Maine stocks. This gap may have been filled by juvenile components from other spawning stocks, namely southwest Nova Scotia, either by an extension of their normal range at the early life-history stage, or by increased survival rates of juveniles. This argument is supported by the change in growth characteristics of 4Xb juveniles that preceded the decline of the 5Y and 5Z adult fisheries by about 3 years and by the similarity of mean length of fish caught in weirs on both sides of the Bay of Fundy since 1972.

Whatever the explanation, it is likely that changes in components of the juvenile-stock structure in the area can be large and relatively rapid, an expression of the resilience in the production system as a whole. The implication is that the accurate assignment of juvenile catches to the appropriate reproductive unit will not be possible unless the juvenile fisheries are monitored in detail and on a time scale appropriate to the mixing phenomena.

Another conclusion to be drawn is that at the present state of our knowledge it is not possible to predict directly, with any precision, year-class size solely from growth parameters of the early life history as has been done for the Californian sardine (Iles 1973). This does not exclude the possibility of other methods becoming established.

The study of stock components of herring within the same area and involving the same life-history stages is of key importance to the development of a satisfactory theory of interactions between taxonomic groups with similar niche requirements (Iles 1980).

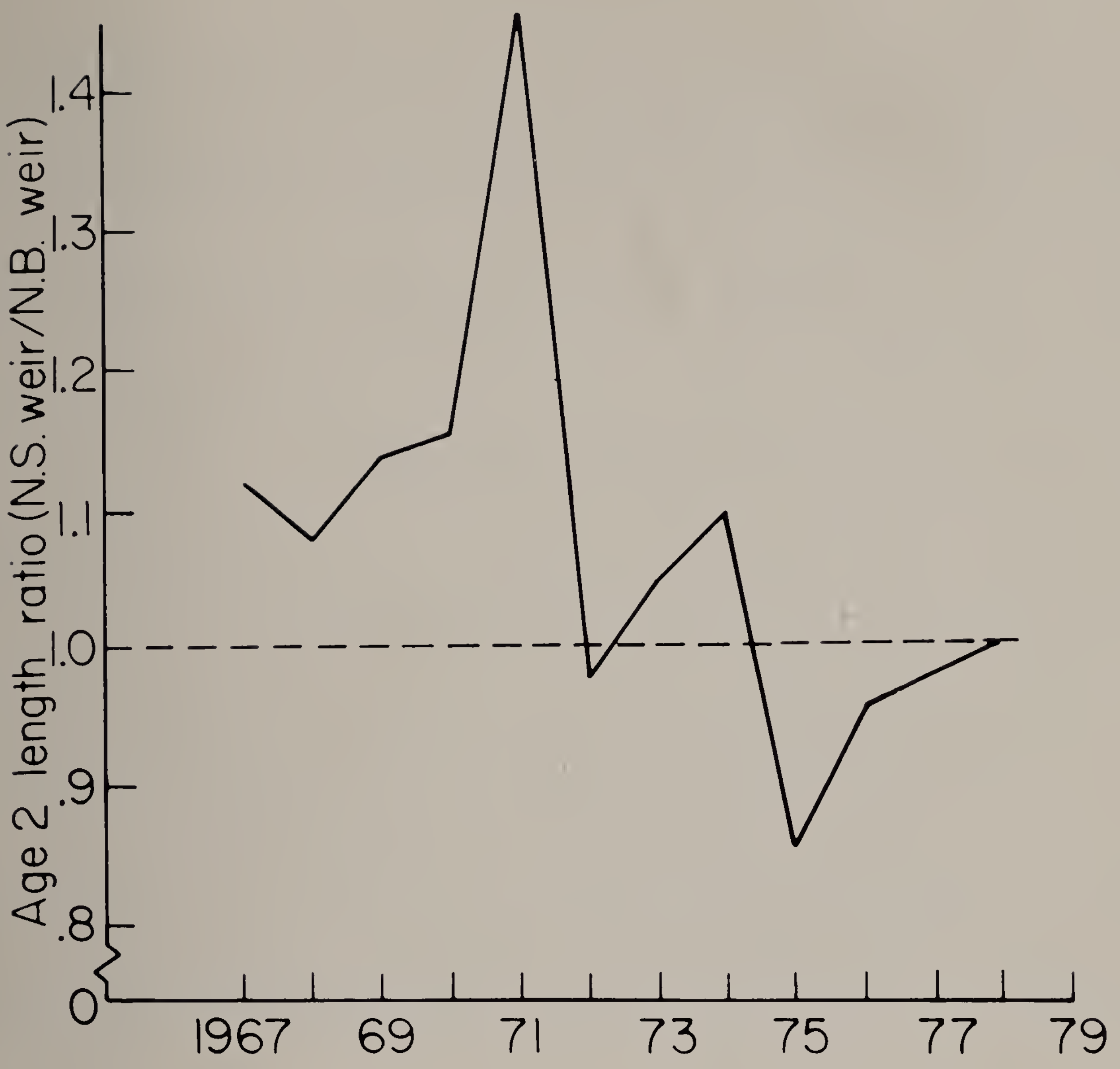

Fig 11. Trend in the ratio of 4Xa and 4Xb weir mean July lengths, age 2, showing a closer correspondence in mean length since 1972.

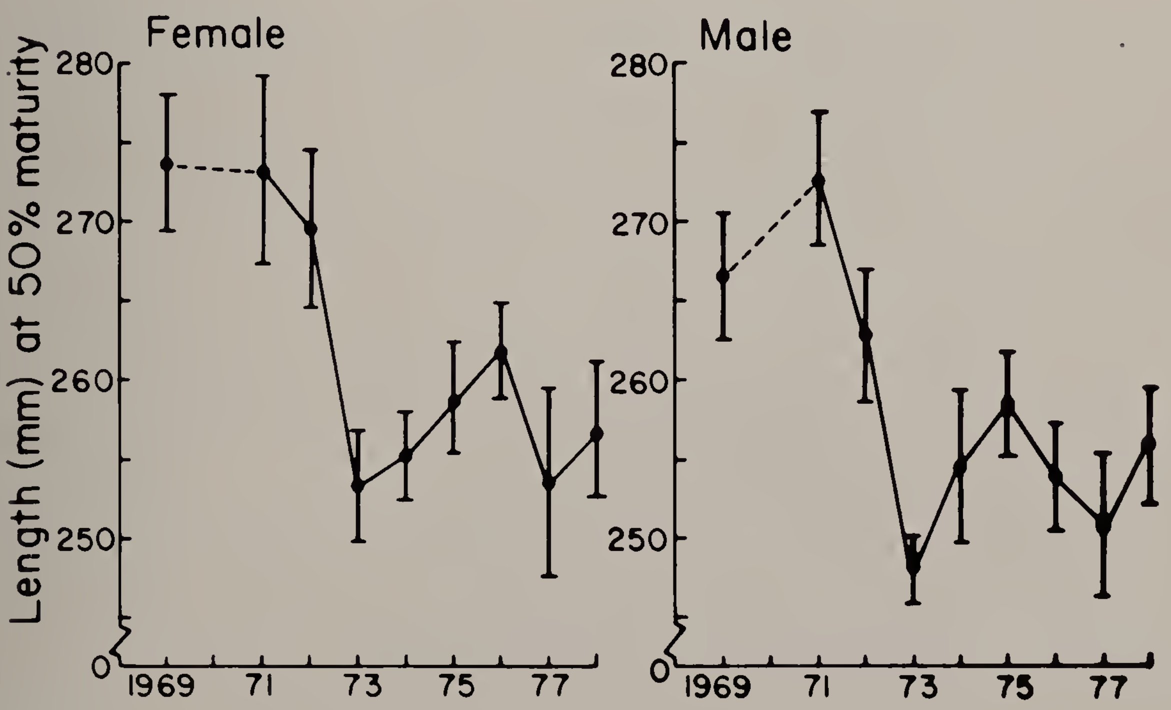

Fig 12. Changes in male and female lengths at 50% maturity. Error bars show the 95% confidence limits.

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THE COPEPODID STAGES OF THE COPEPODS ACARTIA TONSA, A. CLAUSII AND EURYTEMORA HERDMANI FROM THE ANNAPOLIS RIVER, NOVA SCOTIA

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The number of urosome segments, metasome segments, and metasome appendages for *Eurytemora herdmani, Acartia clausii,* and *A. tonsa* is given in tables and figures. These characters may be used to distinguish copepodids during routine examination of plankton samples, but the urosome-cephalothorax ratio is the only way of distinguishing between copepodids of *A. tonsa* and *A. clausii.*

On présente dans des tableaux et des figures le nombre de segments de l'urosome et du métasome ainsi que le nombre d'appendices du métasome d'*Eurytemora herdmani,* d'*Acartia clausii* et d'*A. tonsa.* Ces caractéristiques peuvent servir à distinguer entre eux les copépodites des diverses espèces lors d'examens de routine d'échantillons planctoniques, mais seul le rapport urosome-céphalothorax permet la distinction entre les copépodites d'*A. tonsa* et ceux d'*A. claussi.*

Introduction

There are relatively few publications on the 5 copepodid stages of copepods as most work on larval stages has concentrated on the naupliar stages. Even with published descriptions, it is often difficult to distinguish copepodid stages of species within the same genus. This often necessitates an initial investigation and description for each locality.

Kraefft (1910) gives diagrams of the urosome of *Acartia clausii* copepodids and Grandori (1912) gives diagrams of copepodid stages of *A. clausii* viewed from the dorsal side. Grice (1971) describes the copepodid stages of *Eurytemora herdmani.* The most relevant reference is Conover (1956) who describes the first 3 copepodid stages of *A. clausii* and *A. tonsa.*

Acartia clausii Giesbrecht 1889 sensu stricto is not found in North American waters where the correct species is *A. hudsonica* Pinhey, 1926 (Bradford 1976). Because of extensive use of *A. clausii* for the North American species, the name is retained in this work.

Acartia clausii, A. tonsa, and *Eurytemora herdmani* are the dominant copepods in the headpond of Annapolis River and a detailed redescription of them is given in this paper. Particular emphasis is given to those characters that can be seen during routine examination of plankton samples.

Methods

The copepodids were obtained on 24 July 1980 from the headpond of Annapolis River, in a vertical plankton haul from 6 m. The net had a mesh size of 80 μm Microdissection of the fifth pair of thoracic appendages was completed in a number of adult specimens to assure species identification. Dissected appendages were mounted in polyvinyl lactophenol in which lignin pink had been dissolved.

The diagrams were drawn freehand from specimens examined microscopically while on their side on a drained slide.

Table I. Copepodid stages of *Acartia clausii* and *A. tonsa*.

Copepodid stage:	I	II	III	IV♀	IV♂	V♀	V♂	Ad♀	Ad♂
No. urosome segments	2	2	2	2	3	3	4	3	5
No. metasome segments	3	4	4 or 5	4 or 5	4 or 5	4 or 5	4 or 5	4 or 5	4 or 5
No. metasome appendages	2	3	4	5	5	5	5	5	5
No. swimming feet	2	3	4	4	4	4	4	4	4
cephalothorax length (mm)	0.31-0.37	0.36-0.51	0.43-0.49	0.48-0.59	0.50-0.56	0.54-0.71	0.49-0.61	0.58-0.79	0.61-0.65

Table II. Copepodid stages of *Eurytemora herdmani.*

Copepodid stage:	I	II	III	IV♀	IV♂	V♀	V♂	Ad♀	Ad♂
No. urosome segments	2	2	2	3	3	3	4	3	5
No. metasome segments	3	4	5	4 or 5	4 or 5	5	5	5	5
No. metasome appendages	2	3	4	5	5	5	5	5	5
No. swimming feet	2	3	4	4	4	4	4	4	4
cephalothorax length (mm)	0.30-0.31	0.37-0.38	0.47-0.48	0.49-0.55	0.47-0.51	0.55-0.59	0.51-0.59	0.58-0.60	0.53-0.61

Results and Discussion

The features by which copepodid stages are most easily distinguished are the number of urosome segments, metasome segments, and metasome appendages. These features, as they relate to *Acartia clausii, A. tonsa,* and *Eurytemora herdmani,* are summarized in Tables I and II. The copepod body is divisible into 3 regions: cephalosome, metasome, and urosome (Fig 1c). The metasome is equivalent to the region of "free thoracic segments" (Corkett 1967) and contains the swimming feet and the fifth thoracic appendages. The total number of metasome appendages and swimming feet is entered separately in Tables I and II. As the fifth thoracic appendages do not appear until copepodid IV, the first 3 copepodid stages have only swimming feet on their metasome. The number of pairs of swimming feet in the tables refers only to the fully developed pairs and not to the single rudimentary pair which may be seen as a bud in copepodids I, II, and III.

1. *Acartia clausii* Giesbrecht, 1889 and *Acartia tonsa* Dana, 1849. (Table I).

Conover (1956), in his study of these same 2 *Acartia* species from Long Island Sound, found that the copepodids may be distinguished by the form of the urosome. The relatively shorter urosome in *A. tonsa* gives a lower urosome-cephalothorax ratio than found in *A. clausii.* This ratio, determined for 43 individuals from all copepodid stages, was 1 to 4-4.5 in *A. tonsa* and 1 to 3-3.5 in *A. clausii.* The urosome-cephalothorax ratio is the only practical way of distinguishing *A. tonsa* copepodids from *A. clausii* copepodids. Conover (1956) also states that the caudal rami in *A. tonsa* are quadrate (i.e. are as wide as they are long), whereas in *A. clausii* the rami are longer than wide. These observations were made from a dorsal or ventral viewpoint and are therefore not discernible from the side as illustrated in Figure 1.

Copepodid I (Fig 1a). Two complete swimming legs, the third appearing as a bud. Three metasome segments and 2 urosome segments.

Copepodid II (Fig 1b). Three complete swimming legs, the fourth appearing as a bud. Four metasome and 2 urosome segments.

Copepodid III (Fig 1c). Four complete swimming legs, the fifth appearing as a bud. The fourth and fifth metasome segments have an incomplete division which is seen only ventrally (Fig 1c). This is indicated as 4 or 5 metasome segments in Table I. Two urosome segments.

Copepodid IV (Fig 1d & 1e). Sexes are separable, with the male having 3 urosome segments and the female 2. Metasome with 4 or 5 segments as in copepodid III. There are 4 swimming legs with the fifth appendages being present as a small 2-segmented limb.

Copepodid V (Fig 1f & 1g). Sexes are separable, with the male having 4 urosome segments and the female 3 with a swollen genital segment. Metasome with 4 or 5 segments. Four swimming legs, with the fifth appendages present as a 2-segmented limb similar to that in copepodid IV.

Adults (Table I). The male has a 5-segmented urosome while the female has 3 urosome segments. Metasome with 4 or 5 segments.

2. *Eurytemora herdmani* Thompson & Scott, 1897 (Table I).

The dominant species of *Eurytemora* in the sample is *E. herdmani.* Individuals of a second species were identified as *E. hirundoides* using Wilson (1932) but are recorded here as *E. affinis* because probably all records of *E. hirundoides* from North America are *E. affinis* (Katona 1972).

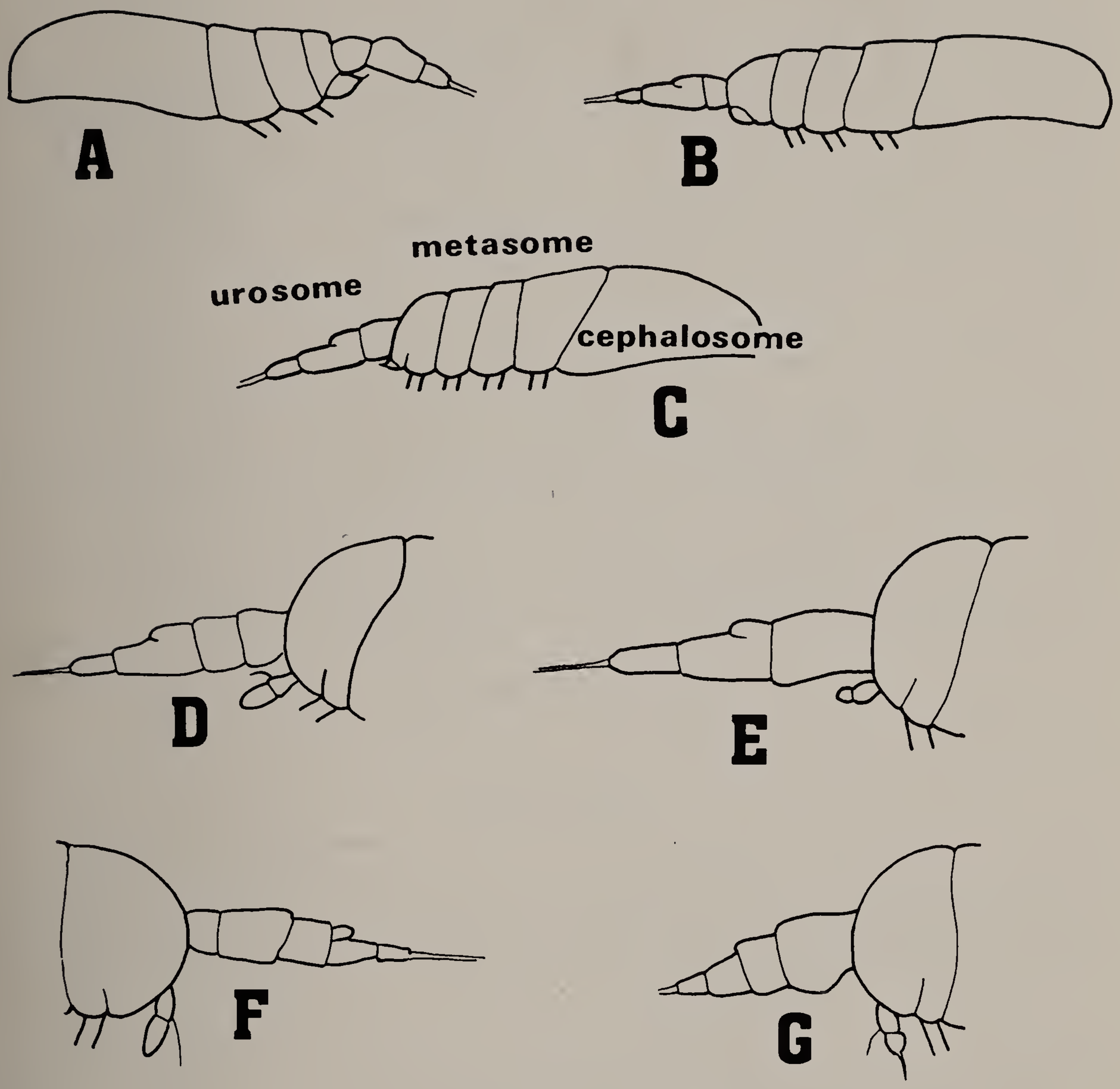

Fig 1. Copepodid stages of *Acartia*. A: *A. clausii* copepodid I; B: *A. tonsa* copepodid II; C: *A. clausii* copepodid III; D: *A. clausii* copepodid IV male; E: *A. clausii* copepodid IV female; F: *A. clausii* copepodid V male; G: *A. tonsa* copepodid V female.

Copepodid I (Fig 2a). Two complete swimming legs, the third appearing as a bud. Three metasome segments and 2 urosome segments.

Copepodid II (Fig 2b). Three complete swimming legs, the fourth appearing as a bud. Four metasome and 2 urosome segments.

Copepodid III (Fig 2c). Four complete swimming legs, the fifth appendage appearing as a bud. Five metasome segments and 2 urosome segments.

Copepodid IV (Fig 2d & 2e). Sexes are separable. The division between the fourth and fifth metasome segment is often incomplete and the metasome thus appears to have 4 (Fig 2e) or 5 (Fig 2d) segments. The urosome has 3 segments in both sexes. There are 4 complete swimming legs and the fifth pair of appendages is sexually dimorphic, being larger and wider in the male (Fig 2d) than in the female (Fig 2e). The sexual dimorphism in the fifth pair of thoracic appendages is the only character that can be used to distinguish the sexes in this copepodid stage.

Copepodid V (Fig 2f & 2g). Sexes are separable. There are 5 metasome segments in both sexes and there is a projection on the postero-lateral corner of the fifth metasome segment in the female. The female urosome has 3 segments, the genital segment being swollen. The male urosome is 4-segmented. There are 4 complete swimming legs and the fifth appendages are sexually dimorphic, the male having a 4-segmented larger and wider pair than the 3-segmented female pair.

Adults (Table II). There are 5 metasome segments in both sexes. The urosome is 3-segmented in the female and 5-segmented in the male.

Acknowledgements

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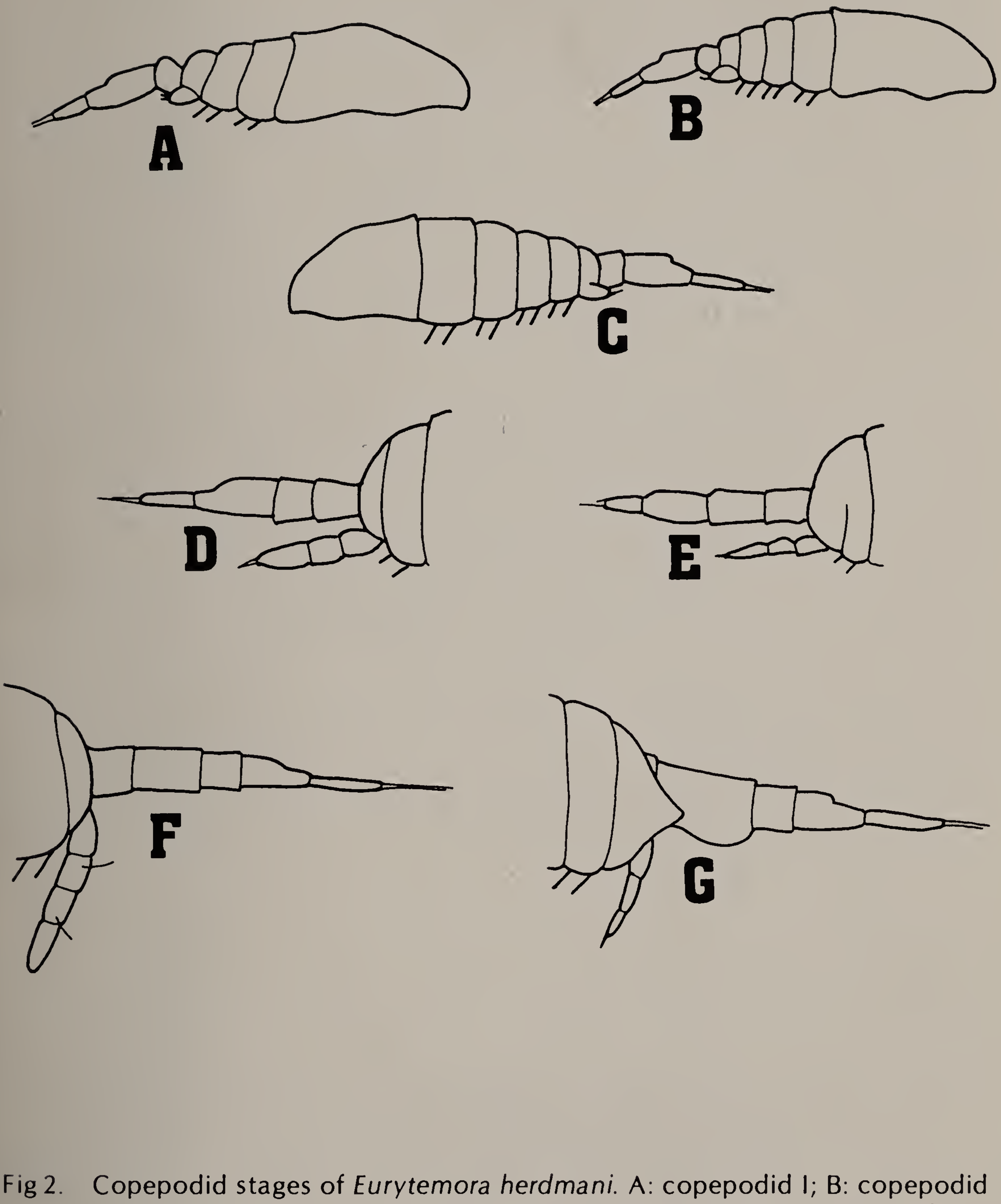

Fig 2. Copepodid stages of *Eurytemora herdmani*. A: copepodid I; B: copepodid II; C: copepodid III; D: copepodid IV male; E: copepodid IV female; F: copepodid V male; G: copepodid V female.

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BAY OF FUNDY BIBLIOGRAPHY: SUPPLEMENT II

The references included herein supplement the recent extensive bibliography, **Moyse, C.M.** 1978. Bay of Fundy Environmental and Tidal Power Bibliography. *Fish. Mar. Ser. Tech. Rep.* No. 822, and its first supplement, *Proc. N.S. Inst. Sci.* (1979), 29:313-314. The present citations were either omitted through oversight or have been published subsequently. All citations received are included, even internal reports that can be difficult to obtain.

This Supplement was prepared with the assistance of the members of the Fundy Environmental Studies Committee.

The Bay of Fundy bibliography will continue to be updated regularly. Any omissions or new references for inclusion should be sent to: DR. D.C. GORDON, **Marine Ecology Laboratory, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, N.S. B2Y 4A2,** and reprints of the present supplement may be obtained by writing this address.

Les références ci-incluses constituent un supplément à la récente bibliographie d'envergure compilée par **C.M. Moyse,** [Bay of Fundy Environmental and Tidal Power Bibliography. *Fish. Mar. Ser. Tech. Rep.* No. 822 (1978)] et à son premier supplément *(Proc. N.S. Inst. Sci.* (1979), 29: 313-314). Les citations qui suivent furent précédemment omises par mégarde ou n'ont été publiées que depuis la parution de la bibliographie et de son supplément. Toutes les citations reçues sont incluses dans le présent supplément, y compris certains rapports internes difficiles à obtenir.

Les membres du Fundy Environmental Studies Committee ont aidé à la rédaction du présent article.

La mise à jour de la bibliographie de la Baie de Fundy se poursuivra de façon régulière. Toute référence omise ou nouvelle devrait être envoyée pour inclusion dans un supplément futur à: DR. D.C. GORDON, **Marine Ecology Laboratory, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, N.S. B2Y 4A2.** Des tirés'à-part de cette publication sont également disponibles à la même adresse.

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INSTRUCTIONS TO AUTHORS

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Spelling should follow that of **Webster's Third New International Dictionary**, and authors are responsible for consistency in spelling.

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BRIEF COMMUNICATION

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La Revue *Proceedings of the Nova Scotian Institute of Science* publie les travaux de l'Institut, des articles originaux et des notes avant trait aux sciences naturelles aux Provinces atlantiques, surtout dans les domaines de la biologie et de la géologie. Les manuscrits peuvent être en anglais ou en français, et seront soumis à l'avis d'experts avant d'être acceptés.

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Volume 31, pp. 187-192

THE INHERITANCE OF SPONTANEOUS PIGMENT MUTATIONS IN CHONDRUS CRISPUS STACKH. (RHODOPHYCEAE).[1]

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Pigmentation mutants of the marine red alga *Chondrus crispus* were collected from intertidal populations and genetically characterized in culture. These mutants had various shades of green pigmentation, bright green at one extreme and brownish green at the other. Of 9 mutants characterized, 6 were found to have strict maternal inheritance whereas the remaining 3 yielded classical Mendelian transmission ratios. Thus both nuclear and non-nuclear, presumably chloroplast, mutants have been identified. One of the Mendelian mutants is very cold-sensitive, being bright green at 5°C and brownish-green at 20°C. It is anticipated that some of the characterized mutants will prove useful for future studies on the biology of *C. crispus*.

Des mutants de pigmentation de l'algue rouge *Chondrus crispus* ont été récoltés dans des populations intertidales et leur génétique a été décrite en culture. Ces mutants sont pigmentés en vert de différents nuances allant du vert clair au vert brunâtre. Des 9 mutants décrits, 6 ont une hérédité strictement maternelle alors que les autres ont une hérédité mendélienne classique. On a ainsi identifié et des mutants nucléaires et des mutants non-nucléaires, ces derniers étant probablement des mutants chloroplastiques. Un des mutants mendéliens est trés sensible à la température: il est vert clair à 5°C et vert brunâtre à 20°C. On s'attend à ce que certains de ces mutants soient utiles pour des études ultérieures de la biologie de *C. crispus*.

Introduction

Chondrus crispus (Irish moss) is a common and commercially harvested red alga in Atlantic Canada. It is, in fact, the only alga in the region that supports a substantial industry, harvests of all other algal species being small by comparison. It is not surprising, therefore, that a considerable amount of research has been devoted to studies on the biology of *C. crispus* in recent years. (Bibliographies of this research have been compiled. See Campbell 1973; Mackey & Taylor 1979).

A workshop on *C. crispus* was convened in 1972 to review what was known about the alga and to focus attention on areas that needed additional study (Harvey & McLachlan 1973). Although much has been learned in the decade following that workshop, many questions remain unanswered or only partly answered. Thus it is likely that research on this alga will still continue for some time.

Up to the present time, most, if not all, research has utilized normal wild plants or populations, in particular a few vegetatively propagated clones of which the Atlantic Research Laboratory's strain "T4" (Shacklock et al. 1973) is perhaps the best known. For some of the anticipated future studies it is likely that mutant plants, in addition to normal plants, will be a valuable asset. Such has been the case in numerous areas of biological and biochemical research, including our own studies on other red algae, namely *Gracilaria tikvahiae* and *Palmaria palmata* (van der Meer 1981; van der Meer & Todd 1980). Because *C. crispus* has a long life

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[1] NRCC No. 19901

cycle that requires almost 2 years to complete even in optimal culture conditions (Chen & McLachlan 1972), a considerable amount of time is required to characterize a mutant strain once a need has been identified. This presents a serious deterrent to the use of mutants. Accordingly, we have decided to characterize some mutants immediately in the anticipation that they will prove useful as markers, and will be ready when needed.

Materials and Methods

Mutant and wild-type fronds were collected at Ketch Harbour and at Finck Cove, both in Halifax County, Nova Scotia. Fronds with altered pigmentation were reasonably common, a single foray often yielding 10 or more mutants. In early spring, when normal fronds are well pigmented, even small mutant sectors can be detected. In summer, when many plants become pale and greenish due to their physiological adaptations to summer growing conditions, mutants are harder, but not impossible, to detect. One of the mutants was obtained from a green sector that arose spontaneously on the T4 clone growing at the ARL marine station.

Apical segments were grown in culture with repeated brushing and trimming until unialgal cultures were established. In some cases the reproductive phase of the plants was known from the onset because the collected plants were fertile; in others, this had to be established in culture. Crosses were made by co-culturing male fronds with unfertilized female fronds grown in solo culture for at least 3 months. In cases where the original mutant frond was tetrasporophytic, male and female plants had to be obtained from tetraspores before genetic testing could begin.

Growth conditions were variable and often not optimal. Plants were usually grown at 20°C, but at times they had to be moved to 5°C to help control a rotting disease which appeared in some cultures. Light intensity varied from 30 to 70 $\mu Em^{-2}s^{-1}$ and included both long and short daylengths. Culture medium was usually SWM-3 without added soil or liver extract (McLachlan 1973), but in some cases Tris buffer was omitted to reduce bacterial growth. Characterization of these mutants was done as a sideline over a period of about 4 years which partly accounts for the culturing variability mentioned. However, this variability in no way affects the validity of the genetic determinations. Under these growing conditions, each phase of the life cycle required about 1 year to reach maturity, and thus at least 2 years were necessary to study the transmission of a mutation through a complete sexual life cycle.

It should be noted here that the strain T4, whose sexuality had not been firmly established at the time, was found to be a male plant when the clone at the marine station produced abundant spermatia during the autumn and winter of 1979. Interestingly, Guiry, working with a subclone of T4 in Ireland, independently discovered at much the same time that T4 could be induced to produce spermatangia in culture (Guiry 1981).

Results and Discussion

Genetic data have now been collected for 9 different mutant plants, all with green or greenish phenotypes. All were spontaneous mutations, 8 of them derived from wild intertidal plants, and 1 from the clone T4 at the ARL marine station. Characteristics of these plants are summarized in Table I. Note that both tetrasporophytes and gametophytes were represented in the original collection.

Table I. Characteristics of the mutants.

Mutant	Color	Phase and Sex	Size of Original Mutant Sector	Sorting-out Pattern of Mutant Tissue
M-1	brownish green	T	whole plant	unknown
M-2	bright green	T	partial frond	gradual
M-3	green	M (T4)	whole frond[a]	unknown[a]
M-4	bright[b] green	M	whole frond	rapid
M-5	yellowish green	M	partial frond	gradual
M-6	pale green	M	partial frond	gradual
M-7	bright green	F	whole frond	unknown
M-8	green	F	whole plant	unknown
M-9	brownish green	F	partial frond	gradual

Abbreviations: T = tetrasporophyte, M = male, F = female

[a] The T4 green clone had arisen years ago and was maintained vegetatively but we have no record for its sorting out.

[b] This color is cold-sensitive. At 5°C it is bright green, but at 20°C it is brownish-green.

Note also that most of the mutants were found as single fronds or sectors of otherwise normal plants. This makes it likely that each is an independent mutation. The absence of bright green complete plants is consistent with the interpretation that most of these mutant phenotypes have a competitive disadvantage, and are not readily propagated in the natural environment. Table I also records, where known, the sorting-out pattern of mutant from wild-type tissue. The sorting out of a nuclear gene would, in most instances, be expected to occur more rapidly than sorting out of a chloroplast gene. Thus from the sorting-out pattern it is possible to predict quite accurately whether a mutation will exhibit a Mendelian or a non-Mendelian transmission pattern.

The results from crosses are summarized in Table II. A control cross between wild-type male and female stocks produced only normal wild-type progeny, indicating that these stocks could be used in crosses to characterize the mutants. The first 2 mutants tabulated were found as tetrasporophytes and although they differed greatly in color, they exhibited identical non-Mendelian transmission in crosses. In both cases, all gametophytes from the original tetrasporophytes had the same mutant phenotype as their parent. Male and female gametophytes were derived from each tetrasporophyte and were crossed reciprocally with the wild type. When mutant females were used, the resulting tetrasporophytes and subsequent gametophytes were mutant. However, when the mutant served as male parent, the mutation was not transmitted. In these crosses, the male's color phenotype was never detected among the thousands of sporelings obtained. These results are identical to those obtained for non-Mendelian mutations of another red alga, *Gracilaria tikvahiae* (van der Meer 1978), which also exhibited a strict maternal transmission pattern.

Mutant males M-5 and M-6 behaved like the males just mentioned and failed to transmit their mutant phenotypes even though these were stable during vegetative growth. Mutant females M-8 and M-9 behaved like the females above in that their diploid progeny had mutant phenotypes, and in that there was no segregation among the F_1 gametophytes. These 4 mutations were also non-Mendelian.

Table II. Summary of crossing results.

Parents (♀ x ♂)	Phenotypes of the Tetrasporophytes	Phenotypes of the F_1 Gametophytes
Control		
wt x wt	wt	all wt
Crosses to wild type		
Unknown parents	brownish green	all brownish green
M-1 x wt	brownish green	all brownish green
wt x M-1	wt	all wt
Unknown parents	bright green	all bright green
M-2 x wt	bright green	all bright green
wt x M-2	wt	all wt
wt x M-3 (T4)	wt	54 wt and 37 green
wt x M-4	wt	115 wt and 123 green
wt x M-5	wt	all wt
wt x M-6	wt	all wt
M-7 x wt	wt	42 wt and 40 bright green
M-8 x wt	green	all green
M-9 x wt	brownish green	all brownish green
Other crosses		
M-9 x M-4	brownish green	247 brownish green and 223 bright green
M-7 x M-3	wt	no data

Abbreviation: wt = wild type

The remaining 3 plants, 2 males (M-3 and M-4) and a female (M-7), had Mendelian transmission of their mutant phenotypes. In each case the mutation was not expressed in the hybrid F_1 tetrasporophyte and reappeared in half of the F_1 gametophytes, a pattern characteristic of a recessive nuclear gene.

Only a few crosses have been made among the mutant stocks themselves. Two, however, are listed in Table II. One cross was between a non-Mendelian green female and a Mendelian green male. The results were consistent with expectations as all progeny were green, but the influence of the recessive Mendelian gene was seen in the segregation pattern of the F_1 gametophytes. The final cross, between 2 recessive Mendelian mutations, showed complementation in the F_1 tetrasporophyte indicating that these mutations are in different cistrons.

Mutant M-4 is unusual when compared with the rest of the collection. Although the color of all the plants can vary somewhat with culture conditions, mutant M-4 is unique in that its color shows a pronounced cold sensitivity. It was found in late winter as a bright green mutation and that color was maintained at 5°C in culture. However, when transferred to 20°C, the color became brownish green, much closer to wild type, although still recognizably mutant. It reverts to bright green upon return to 5°C. The entire plant changes color, not just the newly synthesized tissue.

In summary, it is clear that spontaneous mutations are quite readily obtained both for nuclear and non-nuclear, presumably chloroplast, genes. Both types can be found in the field, although the non-Mendelian type appears to occur more frequently. Only the length of the life cycle presents a problem for genetic analysis, all other factors being straightforward. The sorting-out pattern of mutant tissue was found to be a reliable predictor for the type of mutation present (i.e., nuclear vs. cytoplasmic), and while perhaps not perfect, could be used to select for one kind of mutation or the other.

Having characterized just 9 mutants it is clear we have only begun to scratch the surface of what could be done. Unfortunately the long life cycle of *Chondrus* makes genetic analysis of this alga tedious. Perhaps it is enough to have a few characterized mutant stocks available as tools for future studies. On the other hand, some of the mutants themselves, for example the cold-sensitive green mutant, might well prove interesting for biochemical or physiological studies, which stimulates the desire to have even more mutants. Ultimately these are decisions each investigator will have to make for himself.

Acknowledgements

I thank Edna Todd and Jane Osborne for excellent technical assistance in characterizing these cultures.

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NEW OBSERVATIONS ON THE DISTRIBUTION AND ECOLOGY OF CAVERNULARIA HULTENII IN EASTERN NORTH AMERICA[1]

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In eastern North America, the distribution of *Cavernularia hultenii* has been found to extend from southern Labrador to southwesternmost Nova Scotia. The lichen communities in which *C. hultenii* occurs in Newfoundland and Nova Scotia have been characterized. The diversity of habitats is significantly greater in Newfoundland as the result of a generally cooler and more humid climate to which *C. hultenii* favorably responds. Because of the presence of high humidity niches in the forests of the interior, *C. hultenii* is not exclusively coastal in Newfoundland, whereas in Nova Scotia all known occurrences lie within a narrow coastal strip along the Eastern Shore.

En Amérique du Nord orientale, l'aire de disribution de *Cavernularia hultenii* s'étend du sud du Labrador à l'extrémité sud-ouest de la Nouvelle-Ecosse. On définit dans le présent article les communautés de lichens où l'on rencontre *C. hultenii* à la Terreneuve et en Nouvelle-Ecosse. A la Terreneuve, la diversité des habitats est significativement plus grande à cause d'un climat généralement plus frais et plus humide auquel *C. hultenii* répond favorablement. A cause de la présence de niches écologiques très humides dans la partie intérieure de cette province, *C. hultenii* n'est pas une espèce exclusivement côtière à la Terreneuve, alors qu'en Nouvelle-Ecosse, on ne la retrouve que dans une étroite bande côtière le long de la côte est de la province.

Introduction

Cavernularia hultenii Degel. is a minute and easily overlooked foliose lichen (Figs 1-3) that grows on the twigs of a variety of trees and shrubs and has a strictly oceanic distribution in parts of the boreal-temperate zone adjacent to the Atlantic and Pacific coasts. Following Ahti's discovery of this highly interesting representative of the large family Parmeliaceae in Newfoundland (Ahti 1959), its world distribution was plotted (Ahti & Henssen 1965). Further occurrences in eastern North America were to be expected, and the present paper deals with the distribution and ecology of *C. hultenii* in this part of the world.

Observations

During recent lichenological expeditions to Newfoundland the writer's attention was drawn to *C. hultenii* which was found in nine different situations:

1. On the lowest, very sheltered branches of both *Picea mariana* (Mill.) B.S.P. and *Abies balsamea* (L.) Mill. in ombrotrophic bogs, where they form low and typically prostrate thickets of the Krummholz type that have obviously retarded the growth of *Sphagnum* so that wind-sheltered niches are formed. This habitat was observed in a raised bog south of Pt. Verde as well as in the heathlands between St. Brides and Cape St. Mary's lighthouse which have been studied previously by Ahti (see Ahti 1974).

2. On the branches of *Abies,* forming mixed Krummholz stands with *Picea mariana* in *Diapensia - Empetrum - Loiseleuria - Racomitrium* heath without *Sphagnum.* Seen once on Brunette Island at about 75 m altitude.

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[1] NRCC No. 19904

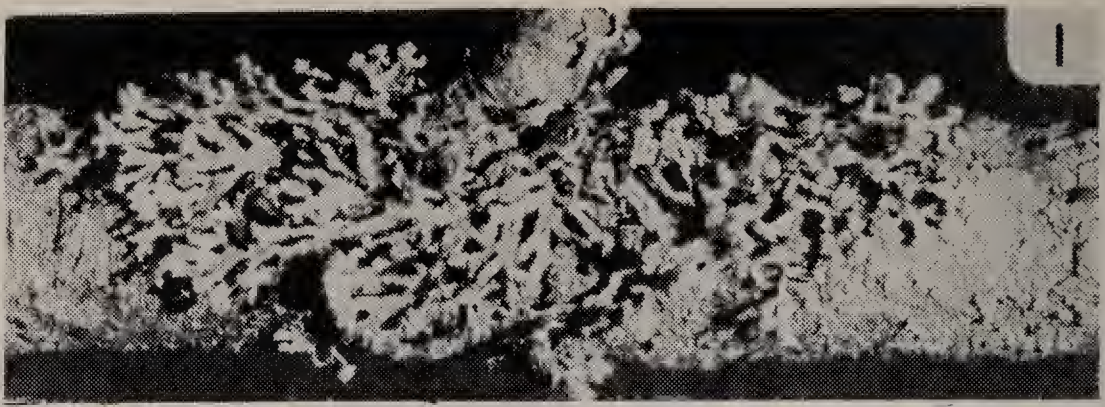

Fig 1. Thallus of *Cavernularia hultenii* on twig of *Abies*. Note the finely divided thallus with the capitate soralia. x 4.

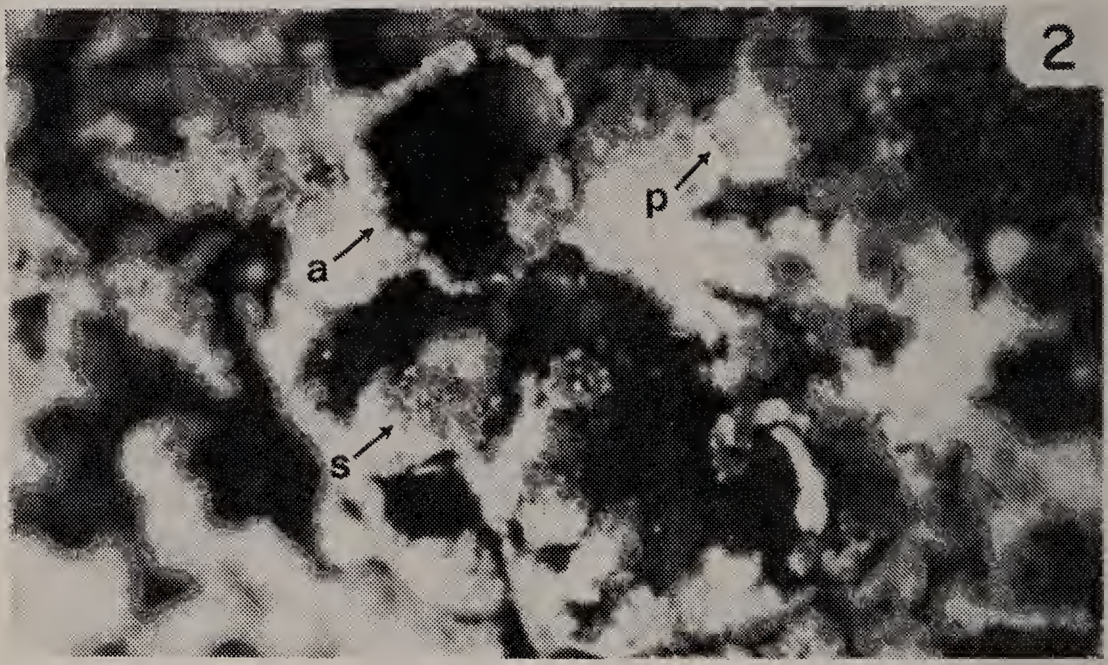

Fig 2. Close-up of *Cavernularia hultenii,* showing an apothecium (a) and the irregularly crenate lobes with soralia (s) and pycnidia (p). x 25. Specimen is from the Queen Charlotte Islands, B.C.

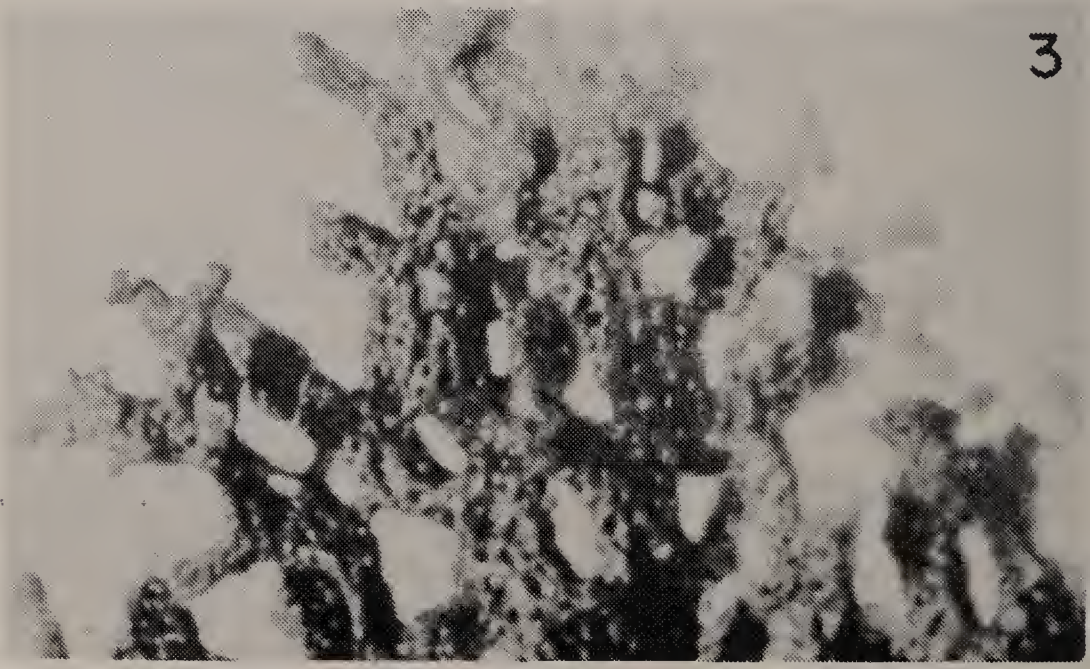

Fig 3. Underside of the thallus of *Cavernularia hultenii,* displaying the characteristic pits or cavernulae, x 15.

3. On the twigs of *Abies* and/or *Picea mariana* in medium-height thickets (see Ahti & Henssen 1965), usually with a spongy ground cover of hepatics *(Bazzania)* and mosses including *Sphagnum*. Often adjacent to maritime heathlands or intergrading into these.

4. On the twigs of younger specimens of *Abies* and/or *Picea mariana* in an otherwise tall and often dense mixed coniferous forest (see Table I in Maass 1980). Typically on slopes.

5. On the branches of mature *Abies* and/or *Picea mariana* or even on deciduous trees including *Alnus* in rather tall but half-open mixed forests. Typically on northerly slopes along swampy brooklets, e.g., on Brunette Island.

6. On the branches of mature *Picea mariana* (and less commonly on those of *Abies*) is half-open successional sphagnous heathland forests of the interior, characterized by an understory of *Kalmia angustifolia* L., *Ledum groenlandicum* Oeder and *Chamaedaphne calyculata* (L.) Moench and by an abundance of *Alectoria sarmentosa* (Ach.) Ach. and *Bryoria* on the trees.

7. On the trunks of *Abies* in mature fir forests which have a closed canopy but little or no *Sphagnum* growing on the ground (Hoisington & Maass 1982).

8. On the branches of *Abies* and *Picea glauca* (Moench) Voss or *P. mariana* (developed either as upright trees or as Krummholz) in sea cliff habitats, usually between 20-70 m altitude and without any *Sphagnum* on the ground (Hoisington & Maass 1982).

9. At the edges of river gorges (Hoisington & Maass 1982).

Subsequently *C. hultenii* was also found in Nova Scotia. As the overall distribution of *C. hultenii* in Newfoundland is going to be discussed in a review article on the biogeography of the lichens of that province (Ahti 1982), an in-

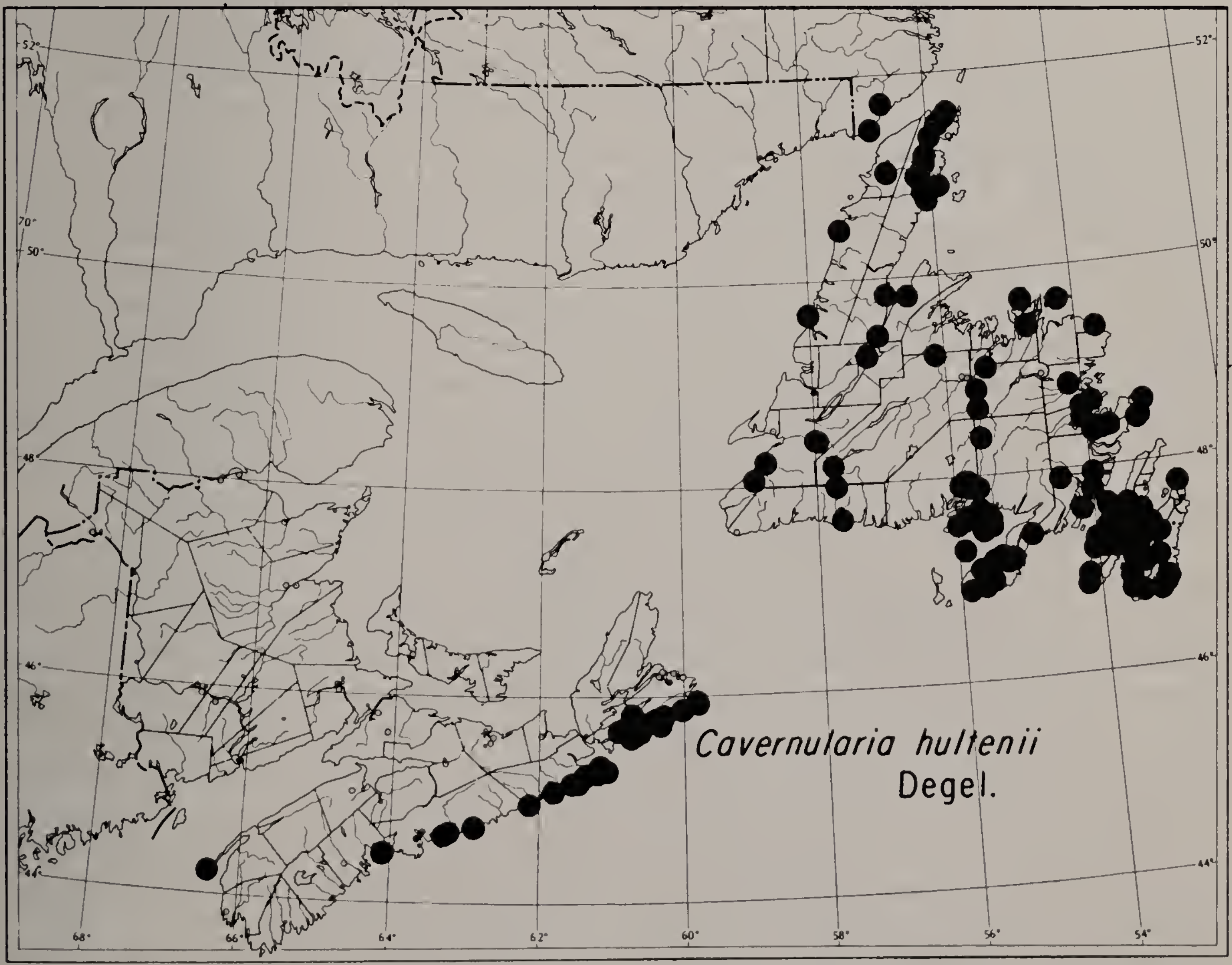

Fig 4. The distribution of *Cavernularia hultenii* in eastern North America.

terpretation of the distribution will be offered here with an emphasis on the Nova Scotian occurrences of *C. hultenii.* This lichen is now known to have a rather continuous distribution in eastern North America from Brier Island, N.S. (44°14′N), to the Pinware River System, Labrador (51°40′N). Within Nova Scotia, it is confined to a very narrow coastal strip of forested land along the Atlantic Ocean (Fig 4). The somewhat isolated Brier Island locality is well known for some southern range extensions of high boreal to subarctic plants including *Betula michauxii* Spach, *Huperzia selago* (L.) Bernh, and *Selaginella selaginoides* (L.) Link (Roland & Smith 1969). However, the actual southern limit of *Cavernularia* in eastern North America may well lie somewhere in the coastal plain between Maine and New Jersey or in the high rainfall areas of the adjacent Appalachian Mountains. The occurrence of *C. hultenii* in mountainous forests is well documented for the Scandinavian Shield (Degelius 1952), and in western North America the lichen follows the coastline at intervals from Alaska as far south as California (Ahti & Henssen 1965). Within Nova Scotia, the frequency of the lichen definitely declines from north to south. The best-explored area is western Halifax County where *C. hultenii* has not yet been found despite the presence of numerous seemingly suitable forest and bog sites. Apart from reasons of incomplete collecting, some of the discontinuous distribution of *C. hultenii* may be explained by pollution from local sources. For instance, the apparent absence of *C. hultenii* from the extensively surveyed western parts of Richmond as well as eastern Cape Breton counties may have resulted from various industrial activities in the Port Hawkesbury, Point Tupper, and Sydney-Glace Bay areas; all of the local fog forest lichen communities that have remained there are unusually depauperate. In addition, the coastal habitats in the Halifax-Dartmouth area may have suffered from urban pollution and those near Liverpool from SO_2 pollution by a pulp and paper mill or small mining operations of the past or present. In spite of surveys of numerous unspoiled localities in Prince Edward Island and on the Cape Breton Highlands *C. hultenii* has not been found there, nor on the coasts of the Northumberland Strait or the Bay of Fundy, including the Fundy National Park (S. Gowan, in verb.), Grand Manan Island, Campobello Island (see Maass 1980) and the adjacent Quoddy Head State Park, Maine. Along the Northumberland Strait, the remaining coastal forests appear too dry (perhaps because of the drier summers there), whereas those of the slightly more humid southern coastal areas of New Brunswick have been severely modified by the presence of pulp and paper mills and other industries. A combination of forest fires and lumbering seems largely responsible for the apparent changes in the forest lichen vegetation on Campobello Island (Maass 1980). Thus, it is possible that *C. hultenii* was once a component of the lichen flora in southern New Brunswick.

In a study of the habitats of *C. hultenii* in northernmost Newfoundland and southern Labrador (Hoisington & Maass 1982) it was concluded that this lichen behaves as a drought-sensitive species. Therefore, it is not surprising that in the Maritime Provinces, *C. hultenii* generally is limited to hyperoceanic sites (i.e., those right next to the outermost coastline of Nova Scotia along the Atlantic Ocean). *Cavernularia* is extremely tolerant of marine aerosols and may even depend on them for either nutritional reasons or because of the decreased acidity of coniferous bark substrates along the coast.

Although *C. hultenii* is most often found on *Abies* (in eastern North America, see Hoisington & Maass 1982), *Picea* (in all parts of the range) and *Betula* (in Scandinavia, see Degelius 1952), it has been observed on a large variety of other substrates. The phorophytes of *C. hultenii* include the lichens *Lobaria pulmonaria* (L.) Hffm. (Hoisington & Maass 1982), *Cetraria ciliaris* Ach. emend. W. Culb. & C. Culb. and *Nephroma bellum* (Spreng.) Tuck. (Hoisington & Maass 1982), the conifers *Abies balsamea* (Ahti & Henssen 1965) including var. *phanerolepis* Fern., *Juniperus* (Degelius 1952), *Larix laricina* (Du Roi) K. Koch, *Picea abies* (L.) Karsten (Ahlner 1948), *P. glauca* (Hoisington & Maass 1982), *P. mariana* (Hoisington & Maass 1982), *P. rubens* Sarg., *P. sitchensis* (Bong.) Carr (Degelius 1937) and *Pinus contorta* Dougl. (Ahti & Henssen 1965), and the angiosperm trees or shrubs *Alnus incana* (L.) Moench (Ahlner 1948), *A. rugosa* (Du Roi) Spreng., *Betula pubescens* Ehrh. including subsp. *tortuosa* (Ledeb.) Nyman (Degelius 1952), *B. papyrifera* Marsh (Hoisington & Maass 1982), *Ledum groenlandicum, Myrica californica* Cham. (Ahti & Henssen 1965), *Nemopanthus mucronata* (L.) Trel. (Ahti & Henssen 1965), *Sorbus aucuparia* L. (Ahlner 1948), *Vaccinium ovatum* Pursh (Ahti & Henssen 1965) and *Viburnum cassinoides* L. This very low substrate specificity allows the lichen to be used as an indicator of miroclimatic habitat conditions (Hoisington & Maass 1982).

Abundant populations of *C. hultenii* have been found in Nova Scotia only near Fort Louisbourg (an area previously visited by Lamb 1954), Fourchu, Clam Harbour Beach and Miseners (Meismers) Head. At the Fort Louisbourg site, a couple of specimens of *C. hultenii* were found to contain galls resembling those found in Labrador (Hoisington & Maass 1982). Although galls have not been reported previously from *Cavernularia* (see review by Grummann 1960), they were collected on *C. hultenii* at least once before (in Sweden, Jämtland, Åre parish, 3 km south of Enafors, on twigs of spruce in a spruce forest, altitude 550-600 m, 16 August 1948 R. Santesson No. 48456, FH). Their description will be provided in a separate study (Maass and Rice 1983).

In Nova Scotia, *C. hultenii* has been seen in the following general types of habitats:

1. In bogs on prostrate to stunted specimens of *Abies, Larix* and *Picea mariana* (only near Fort Louisbourg).
2. In medium-height thickets of *Abies* and/or *Larix* and/or *Picea mariana.*
3. On the branches of medium-height specimens or thickets of *Abies* within the mature coastal *Picea mariana* forests along the boundary of wetlands. These forests usually have a mossy ground cover including *Bazzania* and *Sphagnum* and may contain *Cavernularia* wherever they provide a sufficient shelter from the immediate impact of coastal storms.
4. On the branches of more mature but slightly exposed *Abies, Picea mariana* or *P. rubens* (very rarely on the trunks or over epiphytic lichens) in mixed coniferous forests covering wet slopes adjacent to peatlands or rivers. Usually over mossy ground including *Bazzania* and *Sphagnum.* Rarely on low-lying branches of *Picea* in the fen border of these forests.
5. In sea cliff habitats on the branches of *Picea glauca, P. mariana* and *Abies,* over rather dry ground without any *Bazzania* or *Sphagnum.*

Although basically all of these habitats have been encountered in Newfoundland, a more detailed description of their lichen communities will be given below. The drier heathland, rather dry heathland successional forest, mature fir forest and gorge habitats described from Newfoundland under Nos. 2, 6, 7 and 9 are unknown from Nova Scotia. These habitats may be well depend on the cooler summer climate of the north with its much higher frequency of foggy weather and generally greater relative humidity. In addition, the heathland successional forest of the interior of Newfoundland (habitat No. 6) becomes suitable as a high humidity niche for *Cavernularia* by the very abundant growth of *Alectoria* and *Bryoria* on the coniferous branches. These highly branched fruticose lichens, whose occurrence in the interior is more or less restricted to peatlands in the vicinity of water courses, apparently enhance the humidity of this microhabitat

Fig 5. Two typical bog habitats of *Cavernularia hultenii* near access road to Fort Louisbourg, N.S., including *Abies balsamea, Larix decidua* and *Picea mariana* as phorophytes. The lichen was found inside the medium-tall thickets of conifers in the background as well as on the lowest protected branches of the dwarf conifers that straddle the drier *Sphagnum* ridges in the foreground.

Fig 6. Habitat of *Cavernularia hultenii* in mature forest of *Picea glauca, P. mariana* and *Abies balsamea* around a lagoon behind shingle beach, Miseners Head, N.S. View is in westerly direction.

Fig 7. Overmature forest of *Picea mariana* and *Abies balsamea* with regeneration growth at Clam Harbour Beach, N.S. View is in easterly direction across a flooded fen. *Cavernularia* was found in very dense to half-open, medium-height thickets of *Abies,* as well as on *Alnus incana* and *A. rugosa.*

Fig 8. Habitat of *Cavernularia hultenii* on *Picea glauca* and P. *rubens* in the sunny but somewhat sheltered borders of a narrow coastal fen at Point Michaud, N.S. View is in westerly direction.

9

Fig 9. Coastal cliff habitat of *Cavernularia hultenii* at Baleine, N.S., with stunted forest of *Picea mariana, P. glauca* and *Abies balsamea* at about 20 m altitude.

10

Fig 10. Coastal clif habitat of *Cavernularia hultenii* at Main-à-Dieu, N.S., showing windswept thickets of *Picea glauca* at 5-10 m altitude.

by acting as a buffer. In many of the coastal habitats of *C. hultenii* as well, a lush growth of *Alectoria* and *Bryoria* has been noted.

A number of typical Nova Scotian forest habitats (corresponding to Nos. 1-5) can be seen in Figures 5 to 10. These include free-standing low to medium-height thickets as well as mature and overmature forest sites. Except for the sunny border of these forests, their lichen vegetation is fairly uniform and more strongly controlled by low light levels and high humidity than by the occurrence of specific phorophytes.

In these shaded habitats, *C. hultenii* is often found with *Bacidia chlorantha* (Tuck.) Fink, *Bryoria* (usually juvenile stages of various species), *Hypogymnia physodes* (L.) Nyl., *H. tubulosa* (Schaer.) Hav., *H. vittata* (Ach.) Gas., *Parmelia squarrosa* Hale, *Platismatia glauca* (L.) W. Culb. & C. Culb., *Ramalina thrausta* (Ach.) Nyl. and *Usnea* sp. (usually juvenile stages of various species). In more exposed sites, winds and high light intensities would seem to suppress the development of *C. hultenii* not only in presenting unfavourable conditions per se but in favouring a very luxuriant and competitive growth of many of the lichen species with which *C. hultenii* is normally associated. On the exposed branches of *Abies* and *Picea (P. mariana* and *P. glauca)* along the borders of forests, these species generally tend to form denser communities to the exclusion of *Cavernularia,* because they have a wider ecological amplitude and are better adapted to conditions of periodic drought, bright sunlight, and summer heat. This photophilic lichen community on conifers is best developed on coastal beaches and headlands (over sea cliffs) and is made up of the following members: *Bryoria furcellata* (Fr.) Brodo & D. Hawksw., *B. salazinica* Brodo & D. Hawksw., *B. trichodes* (Michx.) Brodo & D. Hawksw. subsp. *trichodes, B. trichodes* subsp. *americana* (Mot.) Brodo & D. Hawksw., *Caloplaca holocarpa* (Hoffm.) Wade, *C. ferruginea* (Huds.) Th.Fr., *Cetraria ciliaris, C. halei* W. Culb., & C. Culb., *Evernia mesomorpha* Nyl., *Hypogymnia physodes, H. tubulosa, Parmelia squarrosa, Platismatia glauca, P. tuckermanii* (Oakes) W. Culb. & C. Culb., *Ramalina minuscula* Nyl., *R. roesleri* (Hochst. ex Schaer.) Hue, *R. thrausta, Usnea filipendula* Stirt., *U. fulvoreagens* (Räs.) Räs., *U. subfloridana* Stirt., and *Xanthoria polycarpa* (Ehrh.) Oliv. The occurence of *C. hultenii* in this photophilic community was only observed once near Point Michaud, where the habitat consisted of the large low-lying branches of *Picea glauca* and *P. rubens* over *Sphagnum* in the fen border of adjacent coniferous forests (Fig 8). *Cavernularia* was mainly found on the northerly exposed trees where the lichen association of the branches was enriched by large foliose members of the Lobariaceae [*Lobaria pulmonaria, L. scrobiculata* (Scop.) DC. and (more rarely) *Pseudocyphellaria crocata* (L.) Vain.], indicating an unusually high humidity in this habitat (Maass et al. 1982). However, it also occurred on the southerly exposed trees on the opposite side of the narrow fen.

In its normal forest habitats, *C. hultenii* has been seen on slopes of westerly, northerly, and easterly exposures although preferentially near the wet bottom of these slopes such as near Clam Harbour Beach (Fig 7). In this respect it is much less demanding than the exceedingly rare *Erioderma pedicellatum* (Hue) P.M. Jørg. which may occasionally be found in association with *C. hultenii* [in the Lunenburg County locality, east of Clam Habour and near North Fourchu, (Maass 1980; 1982), as well as in Newfoundland (unpublished data)].

Two typical bog habitats from near Fort Louisbourg are seen in Figure 5. One of these is formed by the prostrate thickets of *Abies, Picea,* and *Larix* on the hummocks of *Sphagnum* [predominantly *S. fuscum* (Schimp.) Klinggr., *S. flavicomans* (Card.) Warnst., *S. imbricatum* Russ., and *S. magellanicum* Brid.], as previously observed on the Avalon Peninsula in Newfoundland. The other habitat occurs in the drier parts of this extensive area of ombrotrophic bogs and poor fens and is confined to the inside of taller, medium-height thickets composed of the same species of conifers. These exposed islands of scraggy forest over peatland have probably formed as a successional stage from the low-lying thickets. In these taller thickets, *Cavernularia* seems to be restricted to the innermost branches at breast height but occurs on *Abies, Picea mariana,* and *Larix laricina.* Here it is found in association with *Bryoria trichodes* subsp. *trichodes, B. trichodes* subsp. *americana, Cetraria ciliaris, C. halei, Hypogymnia physodes, Parmelia squarrosa, P. sulcata* Tayl., *Platismatia glauca, P. norvegica* (Lynge) W. Culb. & C. Culb.[1], *P. tuckermanii, Ramalina roesleri, R. thrausta* and *Usnea* sp. In the prostrate thickets, however, *C. hultenii* occurs together with *Hypogymnia physodes, Platismatia glauca* and species indicative of a snow cover during winter such as *Cetraria pinastri* (Scop.) S. Gray, *Parmeliopsis ambigua* (Wulf.) Nyl. and *P. hyperopta* (Ach.) Arn.

Seacliff forest habitats were only seen in northern Nova Scotia (habitat No. 5, Figs 9-10). They were less exposed than the sea cliff habitats encountered in northern Newfoundland and Labrador (Hoisington & Maass 1982).

The Nova Scotian *Cavernularia* habitats No. 3 and No. 4 are floristically very similar and may merely reflect different developmental stages of the forest. However, they have been kept separate to emphasize the medium-height thickets of conifers as an important environment for *Cavernularia* both inside and outside of the mature forests. Such thickets cover extensive peatlands both in southern Newfoundland (Ahti & Henssen 1965) and near the Atlantic coast of Nova Scotia. The thickness of the underlying peat, its rate of decomposition, and the exposure of the site all seem to determine the growth pattern of the conifers and the rate of succession from Krummholz stands (see habitat No. 1) to mature mixed coniferous forests.

The important conclusion to be made from the preceding discussion is that *C. hultenii* would have been able to occupy its present territory in eastern North America relatively early during the post-Pleistocene period of reforestation. It is even possible that it may have survived the late Wisconsinan glaciation on dwarf shrubs in one of the ice-free refugia of western Newfoundland and the Labrador coast proposed by Grant (1977). One of the important dwarf shrubs to consider here as a phorophyte is *Ledum groenlandicum,* on which *C. hultenii* was found near Clam Harbour Beach (in association with *Bryoria trichodes, Hypogymnia physodes, M. tubulosa, Lecanora symmictera* Nyl., Parmelia squarrosa, *Protoblastemia cinnabarina* (Somm.) Räs., and *Usnea trichodea* Ach. For this reason, even though there is no forest today in Greenland to support typically arboricolous lichens, *C. hultenii* may still be expected to occur in Greenland as part of the former land bridge which must have facilitated dispersal between the European and American continents. The most probable sites are sea cliffs with *Ledum groenlandicum* in southwestern Greenland. This area is well known for its rich peatland vegetation with numerous more southerly elements, including the amphiatlantic *Sphagnum pylaesii* Brid. (Lange 1976).

In habitats of *C. hultenii* that have been disrupted by diseases or development, some of the lichen thalli may become exposed to excessive light and assume a yellowish brown instead of the green color that they normally display.

In Nova Scotia, thalli of *C. hultenii* have been found only sporadically on the trunks of conifers (altogether 3 on *Abies,* near Clam Harbour Beach and Ecum Secum, and 1 very depauperate thallus over old exuded resin on *Picea mariana,*

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[1] A rare lichen not previously reported from Nova Scotia.

near Miseners Head). However, in the dense and very mature fir forests of northern Newfoundland they grow exclusively on the trunks, forming a unique habitat (No. 6), especially on the east side of the Great Northern Peninsula. Here they are sometimes associated with *Lobaria scrobiculata* and other cyanophilic lichens.

An early stage of colonization by *C. hultenii* was observed on a second-year shoot of *Abies,* where the lichen consisted of a single narrow lobe which was freely anchored to 2 adjacent green needles. Under the microscope, many lichen thallal initials of uncertain identity could be seen on the upper and lower sides of the needles and it is at least possible that *Cavernularia* may frequently grow as a foliicolous lichen during its early stages of colonization.

Acknowledgements

Dr. Tom Nash III kindly provided me with the apotheciate thallus of *C. hultenii* shown in Figure 2.

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Appendices

All of the collections reported under Appendices 1 and 2 were made between September 1979 and 1981 by Wolfgang S.G. Maass, Barbara L. Hoisington, or both. For an assessment of the chemical ecology of a lichen over a larger geographical area, it may be important to note whether the lichen has been found on twigs or trunks and on *Abies* or *Picea* or on specific deciduous trees or shrubs (Maass et al., unpubl.). Thus, trunk occurrences of *Cavernularia* on *Abies* and *Picea* are symbolized by A and P, and twig occurrences on the same phorophytes by a and p respectively. Other exceptional phorophytes are indicated by genus or full binomial.

Representative specimens have been deposited at CANL and NSPM, and with the appropriate National Park authorities.

1. New localities for *C. hultenii* in Newfoundland.

St. George's Bay Area: Codroy Pond, A; 8 km NE of Robinson's R., A.

Road to Burgeo: 2.4 km NW of Burgeo Motel, 30 m alt., p; 12.9 km S of bridge over Pond River, a; 3.8 km N from bridge over narrows of Peter Stride's Pond near tributary of Victoria River, a, p; Southwest Brook area 30.5 km E from Trans-Canada Highway (TCH), a; Southwest Brook area 23.3 km E from TCH, p.

White Bay Area: on TCH just W of Boot Brook near Sandy Lake, A; Hampden River 1.6 km S of jct. of Hwys. 420 and 421, A, a, p; 16.5 km E of Western Arm on Hwy. 411, A.

Interior: On TCH about 23 km N of Badger, A, p; along Hwy. 360, 29 km N of Miguel's Brook, p; along Hwy. 360, 0.5 km S of the crossing over Miguel's Brook, p; along Hwy. 360, 34.3 km S of the crossing over the Northwest Gander River, a, p.

Bay d'Espoir Area: Between St. Veronica and Long Pond (Jeddore L.) 2 km W from road to the Power Commission, A, a; St. Veronica, 0.7 km E of turnoff to airport between Hwy. 361 and Bay d'Espoir, p; St. Albans, between Swanger Cove and St. Josephs about 3 km from bridge near St. Albans, ca. 60 m alt., a; 3.1 km W from St. Albans, A; near road to Morrisville 6.7 km from Hwy. 361 jct., A, a; 1.4 km N from access road to Jipujijkuei Kuespem Provincial Park, 180 m alt., a; 2.5 km S from access road to Jipujijkuei Kuespem Provincial Park, p.

Hermitage Bay Area: On Hwy. 364, 1.3 km NE of bridge in Sandyville, p; 4.7 km SW of jct. of Hwys. 360 and 364 on road to Hermitage Bay, p; 2.5 km NE of jct. of Hwys. 360 and 364, 45 m alt., a; 2.9 km SW of jct. of Hwys. 360 and 362, a, p.

Fortune Bay—Belle Bay Area: Brunette Island, on S side of central valley, 75 m alt., in *Diapensia - Empetrum - Loiseleuria - Racomitrium* heath with islands of Krummholz, a, and between 15-60 m alt. on steep northerly slopes SSE and NE of the biggest lake, most abundantly on the trunks of *Abies*, A, in dense fir forest, in more open places on *Bryoria*-laden twigs of *Abies*, a, or on *Alnus;* on Hwy. 363, 3.5 km W of turn to Boxey Harbour, a; 2.6 km N of jct. of Hwys. 363 and 362, a; 14.3 km N of jct. of Hwys. 363 and 362, a; 6.1 km S of the turnoff to Pool's Cove on Hwy. 362, a.

Notre Dame Bay - Bonavista Bay Area: Bishops Falls, on TCH about 4.5 km E from Hwy. 360 jct., A; North Twillingate Island, Seabreeze Park, in woods below the lighthouse, a; Chapel Island 2.6 and 3.6 km WNW of turnoff to Boyd's Cove North near Hwy. 340, A; Fogo Island, recreational park near the motel near jct. of Hwys. 333 and 334, A; 2.5 km N of turnoff to Deadman's Bay on Hwy. 330, p; Middle Brook, about 1 km W from turnoff to dump on S side of Hwy. 320, a; Terra Nova National Park, on Hwy. 310 about 1 km E from turn to Burnt Point, p; Terra Nova National Park, along TCH 5.2 km S of Hwy. 310, a; Terra Nova National Park, on Hwy. 301, 2.7 km W from TCH, A; Terra Nova National Park, 2.3 km S of jct. of Hwys. 301 and TCH, A, p.

Bonavista Peninsula: On Hwy. 230, 1 km NNW of Paradise, p; on Hwy. 230, 10.5 km NE of turn to Champney's East, A, a; on Hwy. 230, 4.2 km NE of the road to Champney's East, p; Rattle Falls Natural Scenic Attraction on Hwy. 230, 2.1 km E from Hwy. 235 jct., p; on Hwy. 230, 8.9 km W of turnoff to Charleston, a, p; on Hwy. 230 near Morley's Siding, 0.2 km SW of Hwy. 233 jct., a, p, P, and on *Viburnum cassinoides.*

Burin Peninsula: Between Garnish and Winterland below Hwy. 213 adjacent to a lake, a; SW of Frenchmans's Cove, 1.4 km from Hwy. 210, p, a, A *(Abies balsamea* var. *phanerolepis);* 1.6 km W of turnoff to Molliers NW of Hwy. 210, a; near Lord's Cove in deep scrubby fen vegetation on slope above Hwy. 220, a; 4.1 km ENE of Lawn above Hwy. 220, a; Winterland, 0.4 km S of turnoff to the airport on W side of Hwy. 222, A; 0.7 km W from turnoff to Creston North, near the second ridge SW from Hwy. 210, a; on road to Baine Harbour 1 km from Hwy. 210 jct., A.

Placentia Bay North Area and Isthmus: Merasheen Island, NE part, a, p; headlands of Sandy Harbour River, E side of Long Pond, a; Goobies, 0.7 km S of the jct. of Hwy. 210 with TCH, a, A, p; Jacks Pond Provincial Park, a, A, p, and on *Larix;* near TCH 1.1 km NW and 1.2 km S of Hwy. 203 jct., a, p; and 0.5 km NW of entrance to Bellevue Beach Provincial Park, a.

Avalon Peninsula: 2.5 and 4 km N from Cape St. Mary's, a; St. Brides, near Hwy. 100, 1.6 km W from turnoff to Cape St. Mary's, a; Point Verde, open raised bog, 1 km S of Green Point, p; on road from Southeast Placentia to Colinet (Hwy. 91) 1.7 km W of the turnoff to Dunville, a, p; near Hwy. 91, 0.7 km E of the turnoff to Dunville, above tributary of the Southeast River, 100 m alt., a, p, P; near Hwy. 91, 4.7 km E of the turnoff to Dunville, 105 m alt., p; on Hwy. 102, 1.7 km NNE of Dunville, ca. 90 m alt., p; between Fox Harbour and Ship Harbour 1.3 km SW from Ship Harbour Brook, ca. 90 m alt., a, A, p; along Hwy. 102, 10.6 km NE from Fox Harbour, p, and on *Alnus* and *Larix;* Ship Harbour, near Atlantic Charter Historic Site, p; Fitzgerald's Pond Provincial Park, ca. 135 m alt., p; on Hwy. 101, 1.2 km S of railway crossing, ca. 200 m alt., a; on Hwy. 101, 0.8 km N of railway crossing, ca. 150 m alt., a; Ship Harbour Big Pond on Hwy. 101, 5.4 km N from jct. with Hwy. 100, 160-170 m alt., a, p; on Hwy. 101, 6.8 km S from Hwy. 202 jct., A; on Hwy. 101, 4.1 km S from Hwy. 202 jct., a, p; on Hwy. 101, 3.4 km S from Hwy. 202 jct., a, p; on Hwy. 101, 1.8 km S from Hwy. 202 jct., p; on Hwy. 202, 4.4 km NE of Hwy. 101 jct. near Long Harbour, p; near TCH 1 km SE of Hwy. 202 jct., a, A, p; on Hwy. 100, 7.2 km from TCH jct., a, A, p, and on *Viburnum cassinoides;* near Hwy. 81, 5.3 km S of railway crossing in Whitbourne (just N of Markland), a, p, and on *Nemopanthus;* near Hwy. 81, 11.4 km S of railway crossing in Whitbourne, a, p; Rocky River near Hwy. 81, 10 km N from Hwy. 91 jct. in Colinet, a; on Hwy. 81, 0.3 km S from bridge across Rocky River, 50-60 m alt., p; near Hwy. 91, 1.6 km W of Hwy. 92 jct., near East Branch of the North Harbour River on a wet ridge between Cataracts Brook and North Harbour River, ca. 45 m alt., a, p, and on

Nemopanthus; near Hwy. 91, 2.7 km W of Cataracts Provincial Park, ca. 105 m alt., a, p; Haricot, 1.5 km E from river, a; S of Hwy. 91, 6.1 km E of bridge across Colinet River, ca. 100 m alt., a; on Hwy. 91, 1.9 km W of St. Catherines, about 95 m alt., a; St. Josephs, on Hwy. 90, 1.4 km SE of Hwy. 94 jct., p; Holyrood Provincial Park, a, p; Daniels Point, on Hwy. 10, 2.1 km SW from bridge over Northwest Brook, about 30 m alt., p; between Hwy. 10 and Chance Cove Provincial Park, a; on Hwy. 10, 9.6 km SSW from Cappahayden, p; on Hwy. 13, 9.3 km NW from Hwy. 10 jct., a, p; Salmonier Nature Park, a; on Hwy. 90, 8.4 km S from TCH, a, A, p; near TCH 4.5 km E from Hwy. 90 jct., p; on S side of TCH 1.4 km W of Hwy. 71 jct., a, p; South River system in Conception Bay area, on the road from Clarke's Beach to Snow's Pond, 6.3 km from Hwy. 70 jct. (SW of Halls Town). p; and on Hwy. 73, 2.2 km E from Hwy. 80 jct., p.

2. Collecting data for *C. hultenii* in Nova Scotia.

Cape Breton Co.: Main-à-Dieu, in coniferous thickets on top of sea cliffs, and at edge of fen behind the cliffs, p; Baleine, near the highest coastal rock outcrop, a, p; Fort Louisbourg, between the circumferential road and White Point, a, p, and on *Larix;* 0.1 and 0.8 km W of Landing Cove Brook, a, p; along brook 0.9 km W of Kennington Cove Brook, p; and 4.6 km S of Gabarus Lake (from junction of road to Victoria Bridge), a.

Richmond Co.: Irish Cove, on Hwy. 4, 1.6 km from Cape Breton County line, edge of steep coniferous forest, on trunk of *Picea glauca* over *Cetraria ciliaris;* North Fourchu, 2.4 km from Fourchu Harbour road jct., a; Fourchu, 0.6 km W from Fourchu Harbour road jct., a, p; 1.5 km NW of North Framboise, a, p; near W end of St. Esprit Lake, a; between Fergusons Lake and L'Archeveque 0.6 km W of turnoff to East Side Grand River, a, p; 2.8 km NE of Point Michaud picnic park, a, p; and near Point Michaud picnic park, p; on Hwy. 4, 5.8 km E from St. Peters Canal, p; and on Hwy. 4, 3.4 km W from St. Peters Canal, p.

Guysborough Co.: 2.5 km SE of Little Dover church, a; between Half Island Cove and Fox Island Main, 2.7 km E of Hwy. 316 jct., a; Cole Harbour on S side of Hwy. 316, 0.8 km E from turnoff to village, a, p; Larrys River, 2 km S from turnoff to Lundy, a; Tor Bay, near end of road, 4 km from Hwy. 316 jct., p; New Harbour, 0.5 km S of Hwy. 316 jct., a; Coddles Harbour, 1.8 km E of East Brook, a; Port Bickerton, 0.9 km S of main road jct., p; and just E of Ecum Secum on the narrow peninsula, a, A.

Halifax Co.: Clam Harbour, near bog on road to Owls Head Harbour, a, p, and on *Larix;* SE of Clam Harbour Beach, a, A, and on *Alnus incana, A. rugosa* and *Ledum groenlandicum;* Lower East Chezzetcook, Miseners Head, a, p, P; and causeway opposite Three Fathom Harbour, a.

Lunenburg Co.: Aspotogan Peninsula, New Harbour, a, p.

Digby Co.: Brier Island, below road S from Western Light Road, p, and on slope between Gull Rock Road and valley fen, a.

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CONSIDERATIONS OF FATTY ACIDS IN MENHADEN FROM THE NORTHERN LIMITS OF THE SPECIES

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The comparison of depot fat of menhaden *Brevoortia tyrannus* taken in Nova Scotian waters with other menhaden oils shows surprisingly little difference in qualitative and quantitative detail. It is concluded that the generally higher iodine value of North Atlantic samples compared with Gulf of Mexico samples reflects dietary factors rather than direct environmental effects. Copepods are plentiful in the same waters and modify the fatty acid composition of other fish, but the virtual absence of eicosenoic and docosenoic acids implies that wax esters are not absorbed with conversion of eicosenoic and docosenoic alcohols to the corresponding acids.

La comparaison entre les graisses de réserve de l'alose *Brevoortia tyrannus* capturé dans les eaux de la Nouvelle-Ecosse et celles d'autres aloses ne fait état que de différences étonnament petites tant au point qualificatif qu'au point de vue quantitatif. On conclut que les quantités d'iode en général plus élevées dans les échantillons venant d'Amérique du Nord que dans ceux venant du Golfe du Mexique résultent de facteurs alimentaires plutôt que d'effets environnementaux directs. Il y a une abondance de copépodes dans les mêmes eaux que l'alose et ils modifient la composition en acides gras des autres poissons alors que l'absence de fait des acides eicosénoïque et docosénoïque implique qu'il n'y a pas d'absorption des cires esters suivie d'une conversion des alcools eicosénoïque et docosénoïque en leurs acides correspondants.

Introduction

The Atlantic menhaden, *Brevoortia tyrannus* (Latrobe) 1802, is the principal source of fish meal and fish oil produced along the eastern seaboard of the United States (Tressler 1951; Butler 1967; Simmons 1958; Gruger 1963). Oil production was about 1 x 10^5 tons in 1974 (Anon 1975). The fatty acid composition of the oil was investigated in the late 1950's as part of the interest in relating dietary polyunsaturated fatty acids to serum cholesterol levels in humans (Gruger 1967; Peifer et al. 1962; Peifer 1967; Stansby 1969), and limited analytical compositions have been published for the oil in connection with flavor problems in poultry (e.g. Miller & Robisch 1969; Menge 1971) and swine (Kifer 1967). A comparative analysis of fish-muscle lipids, including Atlantic coast menhaden taken in November, has been published (Gruger et al. 1964). Despite the obvious importance of menhaden, the distribution of depot fatty acids in lots of particular fish has received little attention.

The occurrence of menhaden in Canadian waters may be sporadic (Leim & Scott 1966), although in recent years reports have been fairly numerous (Peppar 1974), including catches in gaspereau nets in January of 1975 in the Bay of Fundy near St. John, N.B. (R.F. Martin, *in verb.*). Changes, purportedly linked to water temperature, have been reported in iodine value of oils produced from fish taken respectively in the Gulf of Mexico or northwards along the Atlantic coast of the United States as far as New Jersey (Simmons 1958; Gruger 1963). A catch of menhaden in southwestern Nova Scotia offered us the opportunity of studying lipids and fatty acids in this species and of determining if any characteristics of the lipid or fatty acids could be ascribed to dietary changes or temperature effects from the colder waters north of Cape Cod.

Materials and Methods

Fish were caught in a seine off the southwest coast of Nova Scotia near Little Harbour, Yarmouth Co., in late June, 1972, and frozen by a commercial firm. Some were shipped to Halifax and in the fall 6 fish weighing about 1 kg each were thawed, weighed, measured, and eviscerated. The bodies were pooled for lipid extraction by the chloroform-methanol procedure of Bligh and Dyer (1959). Bodies were first processed in a Fisk mill and then mixed in a Hobart Silent Cutter. An aliquot was taken for lipid studies. Lipids were separated into polar and neutral fractions on gel columns (Drozdowski & Ackman 1969) with further purification of triglycerides on Adsorbosil-5 "Prekotes" (Applied Science Laboratories, Inc.) developed in hexane:diethyl ether:acetic acid::95:5:1. Methyl esters of triglycerides were prepared and analyzed in both natural and hydrogenated forms on open-tubular gas-liquid chromatography columns as described elsewhere (Ackman & Eaton 1971a; 1971b). A small scale reduction plant in Vancouver (Ackman et al. 1974) provided an oil from whole-fish bodies for comparison. Isolation and identification of unusual fatty acids (Ratnayake 1980) will be published elsewhere.

Results and Discussion

The advanced gonad development (unpublished data) and time of year indicate that our fish should correspond approximately to those found in the usual Atlantic commercial fishery. The moderate fat content of 8.2% for the body suggests however that they had been feeding somewhat less than to the limit of the food supply (Dubrow et al. 1976). This is only one of the difficulties in making comparisons of this type (Stansby 1981). Gruger et al. (1964) recovered 15.5% fat from whole fish by wet rendering. Triglyceride was 85% of the lipid recovered from the bodies of Nova Scotian fish, and the polar lipid, essentially phospholipid, was 15%. These figures are not very dissimilar from those reported for autumn-caught mackerel, *Scomber scombrus* (L.), a typical northwest Atlantic fatty fish from an area overlapping somewhat with the menhaden (Ackman & Eaton 1971b; see also Hardy & Keay 1972, for other lipid details in North Atlantic mackerel). The proportions of the 2 lipid types are similar to those determined by Ueda (1972) for jack mackerel, *Trachurus japonicus* (Temminck & Schlegel). The distribution of lipid among organs and tissues is not exactly the same in all fish with fatty bodies (Ackman 1980), and triglycerides can have varying compositions in different deposits of some species (Ackman & Eaton, 1971b), but not of others (Ackman et al. 1975).

The adult menhaden is a planktivorous fish, remarkable for the efficiency of its filtration process. The commercially produced crude oil has a distinct greenish cast, presumably because of chlorophyll from the phytoplanktic contents of the digestive system. Leim and Scott (1966) reported that copepods and euphausiids are included in the diet. If the menhaden deposits fat in a species-oriented composition, then the triglycerides should reflect the basic plant diet, and the presence of 18:3ω3 at 2.2%, and of a more noticeable amount of 18:4ω3 at 3.8% shows a residual influence of fatty acids from phytoplankters (Ackman et al. 1968; Eaton et al. 1975; see also average composition of phytoplankter fatty acids and discussion in Ackman et al. 1970). Plant fatty acids, such as 16:4ω1 and 18:4ω3, have recently been shown to be high in oils from high-fat feeding capelin and depleted in low-fat spawning capelin (Eaton et al. 1975).

A variety of C_{16} and some C_{18} acids with ω1, ω4, and ω7 unsaturation have been identified in menhaden oil (Ratnayake 1980). The major 16:4ω1 acid was erroneously listed as 16:4ω3 in Ackman et al. (1976). Some of the C_{16} acids were chain extended to 18:2ω4, 18:3ω1, and 18:4ω1, all fatty acids not commonly observed in oils from fish such as herring, mackerel, etc. Other specific analyses of menhaden oils for fatty acids include oils of iodine value 145-147 for 1 year from the Gulf of Mexico, and of iodine value 175 from the Atlantic (Ackman 1980). The median iodine values given by Simmons (1958) or Gruger (1963) are: — gulf (west of Mississippi delta) 152.7; gulf (east of Mississippi delta) 152.5; east coast of Florida, 157.5; Carolinas, 162.8; Chesapeake Bay, 169.2, South Jersey and Delaware, 182.6; and northern New Jersey and Long Island, 176.6. Superficially this indicates that iodine values increase as the production site moves north and the common view (Storch 1966; Stickney 1971; Linden et al. 1973; Fuller et al. 1974; Yavin & Menkes 1974a, 1974b; de Torrengo & Brenner 1976; Wodtke 1978; Hazel 1979; Vigh et al, 1979) would be that this is a reflection of a decrease in water temperature affecting the metabolic needs of the fish. However, it is equally probable that the fatty acids of the food are only partially modified or selected, and deposition in depot fat therefore reflects a dietary factor.

Other analyses not included in Table I (e.g. Hallgren & Stenhagen 1960; Gruger et al. 1964; Peifer et al. 1962; Gauglitz 1967) report quite remarkable variations in individual components. It is worthy of note that neutral lipids from juvenile menhaden (78-83 mm fork length) taken in Virginian waters, and presumably in the carnivorous stage, resemble our adults in fatty acid composition, being slightly higher in 16:0 and lower in 20:5ω3 (Weaver 1974). Dietary fatty acids vary in proportion with food (Jeffries 1975).

Changes in gas-liquid chromatographic detectors and other technological considerations make examination of some details and comparisons of small changes in some fatty acids difficult to interpret unless they are done as a sample group or series in one laboratory. One set of published data (Gruger 1963) shows that the percentage of 22:6ω3 in commercial menhaden oil produced at definite locations in 1960 varied as follows: — Empire, La. (Gulf of Mexico) 3.3; Fernandina Beach, Fla. (Atlantic Coast) 5.0; Beaufort, N.C. 5.0; Port Monmouth, N.J. 5.1 (May); 6.5 (July). Samples specified only as "south" and "north" had 4.8% and 5.6% respectively. It is not always known if samples such as that marked "Reedville" are winterized (cold-cleared, which increases iodine value because the oil then includes more 20:5ω3 and 22:6ω3), but it is clear that the oil from Nova Scotian menhaden has more 22:6ω3 and less 20:5ω3 than oil from Gulf of Mexico fish. It should be specifically noted that the "European" menhaden sample is a blend of several shipments of unwinterized oil.

Analyses of fatty acids of the oil from reduction of whole fish taken off Nova Scotia, and of fatty acids of triglycerides from the body are in reasonable agreement, and show less 16:1 and more 18:1 than the other oils on Table I. This point is of interest because we have found 16:1>18:1 in Nova Scotian sand launce *Ammodytes americanus* DeKay 1842, whereas in European waters this species has

18:1 16:1 (Ackman & Eaton 1971a). This type of systematic difference, also noted in some oils from capelin, *Mallotus villosus* (Müller) 1777, where 16:1>18:1 is observed in Canadian oils, (Eaton et al, 1975). The observation that 18:1 exceeds 16:1 in menhaden from off Nova Scotia, a proportion quite different from the Gulf samples, is supported by 3 other Gulf samples (Ackman 1980), where the ratio of 18:1 to 16:1 was about 2:3. This is probably important, as in another set of analyses (Gruger 1963), 18:1>16:1 is definitely associated with a colder time of year (May) for a Fort Monmouth, N.J. sample, or the sample of unspecified origin marked "north". As noted earlier, the possibility of technical problems affecting results must always be kept in mind, but it seems reasonably established that in addition to a higher iodine value for oils of more northerly origin, they are marked by 18:1>16:1. Adult menhaden basically sweep up a considerable proportion of phytoplankters (Reintjes 1969). Probably they also ingest some lipids from copepods containing wax esters (Ratnayake & Ackman 1979a; 1979b) and possibly from common euphausids (Ackman et al. 1970). Plants essentially lack 20:1 and 22:1 (Ackman et al. 1970). The menhaden oils differ from the oils of other North Atlantic fatty fish, such as sand launce (Ackman & Eaton 1971a), capelin (Eaton et al. 1975), and herring (Addison et al. 1969), in having 16:1 and 18:1 as almost the only monoethylenic fatty acids, whereas the oils of sand launce, capelin, herring, and mackerel all have at least 10% (total) 20:1 + 22:1. These 2 longer-chain fatty acids are replaced in menhaden oil by higher (25-30 w/w%) total proportions of 14:0, 16:0 and even 18:0, which seldom total more than 20 to 25 w/w% in the other fish oils from Nova Scotian waters.

One monoethylenic fatty acid isomer detail for Nova Scotian fish (Ackman et al. 1976) suggests that when fatty acids are biosynthesized in the menhaden, the route 16:0→18:0→18:1ω9 is preferred over 16:0→16.1ω7→18:1ω7. In considering a large number of samples of monoethylenic fatty acids of marine origin, we have concluded that the former route is taken when food supply is adequate and additional unsaturated acids are not required. The latter route seems to be taken when there is a requirement for unsaturated acids, but is also postulated to take place in capelin in the autumn, when they are feeding heavily, to modify excess 16:0 originating in the C_{16} wax ester alcohol and acid from copepods (Eaton et al. 1975). The low proportion of 18:1ω7 to 18:1ω9 in the Nova Scotian menhaden, compared with Gulf of Mexico fish (Ackman 1980), suggests that zooplankters the wax-rich copepod type are not important in the diet of this particular lot of menhaden. This view is reinforced by the virtual absence of the 22:1ω11 (and accompanying 20:1ω9) fatty acids of copepod fatty alcohol origin (Ackman et al. 1980; Ratnayake & Ackman 1979a; 1979b). It is remotely possible that menhaden lack the digestive system enzyme which must be present in most pelagic fish (Patton et al. 1975; Sargent et al. 1979) to promote absorption of the 22:1 alcohol. This process leads to the 22:1 fatty acid in the depot fats of herring, mackerel etc. taken in the same area as the Nova Scotian menhaden (Ackman et al. 1980).

The preponderence of analyses showing 20:5ω3>22:6ω3 strongly suggests the close link between menhaden and phytoplankters. Our details on the inclusion of 16:2ω4, 16:3ω4 and 16:4ω1 (Ratnayake 1980), and the 18:3ω3 and 18:4ω3, also of plant origin, support this view. The 20:5ω3 is almost certainly accumulated in large part directly from its plant origin (see Ackman et al. 1968; 1970), and can be converted to 22:6ω3. We suggest that chain extensions and other complex fatty acid transformation in menhaden fatty acid biochemistry emphasize disposal of the 18:2ω6 and 18:3ω3 plentiful in the phytoplankters respectively by catabolism of almost all ingested 18:2ω6, and excess 18:3ω3, and by conversion of some 18:3ω3 to 20:5ω3 and/or 22:6ω3. Notwithstanding differences among menhaden

Table I. Proportions of selected fatty acids (w/w%) of menhaden triglycerides and commercial oils.

	Nova Scotian Fish Triglycerides		Other Reduction Oils					
	Laboratory Extract of Body Only	Pilot Plant Reduction of Whole Fish						
	Halifax Extract	Vancouver Reduction	Reedville[a] (Virginia)	Atlantic[b] (New Jersey)	Gulf of Mexico		Average USA[a]	As Exported to Europe[c]
14:0	8.1	7.9	10.2	10.6	11.8[a]	13.5[b]	12.0	7.3
16:0	25.4	21.5	22.2	23.6	21.8	22.4	22.0	19.0
18:0	4.3	3.1	2.7	3.0	2.7	2.6	2.9	4.2
16:1	8.8	10.4	12.3	14.8	16.2	17.3	14.9	9.0
18:1	17.2	18.8	10.7	12.6	11.9	14.1	17.6	13.2
20:1	1.8	1.4	3.2*	2.7	2.1*	1.6	2.2*	2.0
22:1	0.1	0.5	1.3	1.0	1.4	0.9	1.0	0.6
18:2ω6	2.7	1.4	3.5	1.2	2.3	0.9	1.2	1.3
18:3ω3	2.3	1.4	-	1.0	-	0.4	-	1.3
18:4ω3	3.8	2.9	3.8	0.9	2.6	1.1	1.2	2.8
20:4ω6	0.3	0.1	1.1	0.8	1.6	0.8	0.9	0.2
20:5ω3	10.1	11.6	13.8	13.1	13.2	13.5	11.5	11.0
22:5ω3	0.4	0.3	2.2	1.4	1.4	1.5	1.4	1.9
22:6ω3	8.3	9.2	9.9	6.5	6.0	3.3	5.5	9.1
Iodine Value	138	148	184	-	158	-	-	162

*includes 18:3ω3

[a] Unpublished data courtesy of E.H. Gruger

[b] Gruger (1963), also published in Stansby (1969).

[c] Unilever Research, Vlaardingen, *in litt.*, reproduced by permission of W. Schokker and H. Boerma.

oils, the fatty acid patterns in the triglycerides fit quite well into general marine oil patterns (Harlow et al. 1966; Litchfield et al. 1967; Litchfield 1973).

In cultured rat-brain cells the conversion 18:3ω3→20:5ω3→22:6ω3 may be a 2-step and temperature-dependent process (Yavin & Menkes 1974a), but it is not known if fish require 1 or 2 steps. The basic problem is that studies of this type in fish usually apply to functional membrane *lipids* (de Torrengo & Brenner 1976; Wodtke 1978; Hazel 1979). Very little has been done on the influence of temperature on the fatty acids of triglycerides (Leger et al. 1977). Menhaden have adapted to an environment niche by eating organisms relatively low in fat, by depositing some fatty acids (e.g., 20:5ω3) relatively unchanged, and by converting other food material to the readily biosynthesized saturated acids and their desaturated monoethylenic analogues. It does not seem necessary to involve lower water temperature in northerly latitudes and functional fish biochemistry to account for the higher iodine value of menhaden *oils*. Rather this seems to be a case of a species-peculiar composition dictated by both a minimum energy expenditure on conversion of ingested food and the absence of low iodine value 20:1 and 22:1. We postulate that it is the higher degree of unsaturation of the plant food organisms *in toto* (cf. Vigh et al. 1979), rather than geographic and environmental influence acting directly on the metabolism of the menhaden, which modifies the iodine value of the depot fats and resulting commercial oils.

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MERCURY BIOACCUMULATION IN THE DETRITUS-FEEDING BENTHIC INVERTEBRATE, HYALELLA AZTECA (SAUSSURE)[1]

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Uptake and retention of ingested methylmercury and inorganic divalent mercury from the gastrointestinal tract of the freshwater amphipod, *Hyalella azteca* (Saussure) were estimated by radiotracer techniques. The mercury-contaminated food items consisted of 3 species of algae *(Scenedesmus quadricauda, Anabaena flos-aquae,* and *Navicula pelliculosa)* and pulverized autumn maple leaves. The net assimilation of methylmercury into body tissues was 70-80% of the amount present in the ingested diet compared to 3-8% for inorganic divalent mercury. Clearance of methylmercury from the body tissues of *Hyalella azteca* was a first-order process with a halflife of about 30 da. A positive relation was observed between ingestion rate and whole-body retention. Clearance rate did not increase with temperature, over a range in temperature of 10-20°C. The assimilation from water strongly favors the preferential bioaccumulation of methylmercury compared to divalent mercuric ion. The efficiency of methylmercury removal from water by the amphipod is equivalent to approximately 15-20% of the efficiency of oxygen uptake from water. Inorganic mercury is taken up from the water by *Hyalella azteca* at a slower rate (2-3 times more slowly) than methylmercury. There was no evidence of an appreciable "in vivo" conversion of inorganic mercuric ion, present in tissues, to organic forms of mercury. However, slow "in vivo" conversion of methylmercury to inorganic mercury may be an important factor in elimination of methylmercury from tissues.

Les taux d'absorption du méthyl-mercure et de mercure inorganique divalent dans le système gastrointestinal de l'amphipode dulcicole *Hyalella axteca* (Saussure) ont été estimés à l'aide de traceurs radioactifs. Trois espèces d'algues *(Scenedesmus quadricauda, Anabaena flos-aquae* et *Navicula pelliculosa)* et des feuilles automnales pulvérisées d'érable constituaient les aliments contaminés par le mercure. De 70% à 80% du méthyl-mercure présent dans l'ingesta est assimilé dans les tissus contre seulement de 3 à 8% du mercure inorganique divalent. L'élimination du mercure des tissus d'*Hyalella azteca* est un processus du premier ordre et a une demi-vie d'environ trente jours. On a observé une relation positive entre le taux d'ingestion et la rétention dans le corps dans son ensemble. Le taux d'élimination n'augmente pas avec la température pour des températures comprises entre 10 et 20°C. L'assimilation à partir de l'eau favorise fortement la bio-accumulation du méthyl-mercure par rapport à celle de l'ion mercurique divalent. L'efficacité de l'absorption du méthyl-mercure de l'eau par l'amphipode équivaut à environ de 15 à 20% de son efficacité à absorber l'oxygène de l'eau. Le mercure inorganique est absorbé de l'eau par *Hyalella azteca* à un taux 2 à 3 fois inférieur à celui de l'absorption du méthyl-mercure. On n'a trouvé aucun signe d'une transformation significative "in vivo" de l'ion mercurique inorganique présent dans les tissus en mercure organique. Toutefois, il se peut qu'une lente transformation "in vivo" du méthyl-mercure en mercure inorganique soit un facteur important dans le processus d'élimination du méthyl-mercure des tissus.

[1] NRCC No. 19902

Introduction

Benthic invertebrates can be expected to mediate mercury flux by 3 distinctly different mechanisms. The most obvious mechanism involves mechanical agitation of sediments by movement of the organisms (Boddington et al. 1979). The second mechanism is by direct uptake of mercury from water as is common to all aquatic organisms. The third mechanism is by ingestion of mercury-contaminated detrital material and other food items.

Uptake rate constants for inorganic (mercuric chloride) and organic mercury (methylmercuric chloride) and whole-body clearance rates have been reported for various species of fish (Jarvenpaa et al. 1970; de Freitas et al. 1977; Sharpe et al. 1977). These rate constants have been used to explain: 1) the levels of mercury observed in wild populations or organisms (Fagerstrom & Asell 1973; Norstrom et al. 1976) and 2) the relative magnitude of the food and water vector (de Freitas et al. 1974; Fagerstrom et al. 1974; Norstrom et al. 1976). Corresponding parameter values for mercury dynamics in benthic organisms are not available, and the question arises, then, as to the similarity between invertebrates and fish in their ability to assimilate and eliminate mercury.

In order to help clarify the role of amphipods in the mobilization and transport of mercury to benthophagous fish, we worked with the freshwater amphipod *Hyalella azteca* (Saussure) fed defined algal food material contaminated with ^{203}Hg-labelled methylmercuric chloride (CH_3HgCl) and mercuric chloride ($HgCl_2$). The efficiency of mercury assimilation from the gastrointestinal tract and subsequent clearance of both forms of mercury was measured. Also measured was the amount of mercury absorbed directly from water by amphipods exposed to water contaminated with CH_3HgCl and $HgCl_2$.

Methods

Maintenance of Experimental Animals

The amphipod, *Hyalella azteca*, was obtained from Carolina Biological Supplies[1] and maintained in a 45-*l* aquarium half-filled with dechlorinated tap water under constant aeration. The aquarium contained a layer of sediment, approximately 1 cm deep, from the Ottawa River and the aquatic plants, *Myriophyllum, Elodea* and *Lemna*. Approximately half of the water in the aquarium was replaced every 2 weeks with fresh dechorinated tap water. The system was maintained on a 14:10-h light:dark cycle at a water temperature of 19 ± 1 °C. In all of the experiments the head length of the amphipods was measured to minimize differences in results due to body size, but amphipods were not separated by their stage of intermoult.

Handling of ^{203}Hg-labelled Compounds

Mercury-203 is a gamma-emitting isotope allowing easy measurement of mercury taken up by amphipods from contaminated food and water. The amount retained in subsequent periods is estimated from whole-body ^{203}Hg counts of live amphipods. Compounds labelled with ^{203}Hg were purchased from New England Nuclear[2] as aqueous solutions of $CH_3{}^{203}HgCl$ and $^{203}HgCl_2$, with specific activities at time of purchase of 2.7 to 5.2 mCi mg^{-1} and 4 mCi mg^{-1} mercury respectively. The ^{203}Hg-labelled material, as supplied, was diluted with distilled water and stored in 15-ml vacutainer tubes[3]. The initial concentration of radioactivity

[1] Carolina Biological Supply Company, Burlington, North Carolina

[2] 575 Albany Street, Boston, Massachusetts, 02118, U.S.A.

[3] Evacuated glass tubes, 127x16 mm., Becton-Dickinson, Division of Becton, Dickinson and Company, Rutherford, New Jersey.

in the diluted stock was usually 20 μCi mg^{-1}. At this concentration, methylmercury does not undergo radiation-induced chemical breakdown, and can be used for up to 6 months after purchase without a significant increase in the level of ^{203}Hg-labelled impurities (Sharpe et al. 1977).

The counting efficiency of the deep well scintillation counter[4] was determined by the use of a standard containing a ^{203}Hg-labelled $HgCl_2$ solution in a sealed glass ampoule within a standard scintillation vial. This standard was used to determine the day-to-day variations in counting efficiency observed during the extended periods of measurements.

A modification of the Westoo procedure (Westoo 1967), was used for separating organic mercury from inorganic mercury. Exposure medium was analysed as follows: a 10-ml sample was placed in a 50-ml stoppered graduated cylinder to which was added 0.5 ml of an aqueous solution containing 250 μg of CH_3HgCl and 250 μg of $HgCl_2$; aliquots (0.25 ml) of 1000 μg ml^{-1} solutions of CH_3HgCl and $HgCl_2$ were added as carrier material; NaCl (2.0 g), concentrated HCl (3.5 ml) and benzene (20 ml) were added and the mixture stoppered and shaken for 30 seconds; the mixture was allowed to stand until the phases separated; the benzene layer was removed and placed in a 100-ml graduated cylinder; the benzene extraction was repeated 2 more times and the extract transferred to the 100-ml graduated cylinder; final volumes of the aqueous phase and benzene phase were recorded; a 5-ml sample of each phase was placed in separate sample vials for measurement of radioactivity.

A similar procedure was used for separating the organic and inorganic mercury fractions present in individual amphipods and mercury-contaminated foods. The amphipod was first homogenized in a 15-ml glass centrifuge tube modified to function as an all-glass homogenizer with matching ground glass rod. To analyse food, approximately 10 mg wet weight of food was added directly to the centrifuge tube, followed by 2 ml distilled water, 2 ml benzene, 0.25 ml each of CH_3HgCl (1000 μg Hg ml^{-1}) and $HgCl_2$ (1000 μg Hg ml^{-1}), 0.7 ml concentrated HCl and 0.4 g NaCl. The contents were mixed on a vortex mixer for 30 seconds, then centrifuged. The benzene layer was removed and placed in a scintillation vial and the benzene extraction repeated twice. The entire benzene fraction and aqueous fraction (each in separate scintillation vials) were then assayed for radioactivity.

Mercury Dosing Procedures

Foods contaminated with mercury were: the green alga, *Scenedesmus quadricauda* (Indiana University Collection[5] No. 77); the bluegreen alga, *Anabaena flos-aquae*, (I.U. No. 1444); and the diatom, *Navicula pelliculosa*, (I.U. No. 668). The background level of mercury in these algae prior to addition of ^{203}Hg-labelled solutions, was 315 ppb on a dry-weight basis, using adaptation of the Magos (1971) procedure for atomic absorption determination of total mercury, as described by Norstrom and Peter (1972). These background levels were less than 5% of the mercury levels in the mercury-contaminated foods used in the feeding experiments.

To prepare amphipods for a feeding experiment, 15 to 30 amphipods were removed from their culture tank and placed in a 2-*l* glass beaker containing 1800 ml dechlorinated tap water and the uncontaminated version of the diet to be used in the experiment. After a 24-hour acclimation period, the amphipods were placed in another 2-*l* glass beaker containing 1800 ml dechlorinated tap water

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[4] Ino-tech 5100 multichannel analyzer coupled to a 5-cm diameter NaI doughnut crystal detection unit. Counting efficiency for ^{203}Hg was approximately 40%.

[5] Culture Collection of Algae, Dept. of Botany, Indiana University, Bloomington, Indiana.

but no food and then held for 2 hours before addition of the mercury contaminated diet.

Mercury-contaminated food was prepared by adding approximately 350 mg (wet weight) of live algae to a 20-ml glass test tube containing dechlorinated tap water and ^{203}Hg-labelled CH_3HgCl or $HgCl_2$. The tube was shaken for 2 hours, centrifuged, the water layer decanted off, and fresh dechlorinated tap water added. To remove mercury that was not firmly bound, the tube was mixed for 30 seconds on a vortex mixer and centrifuged again. This procedure was repeated 4 to 6 times until only 2% or less of the mercury was lost per rinse. Distribution of the firmly bound mercury was not examined, but it has been reported that both methylmercury and inorganic mercury are absorbed into plant cells, and remain firmly bound to intracellular components (Czuba & Mortimer 1980). An excess of food (approximately 30 times the amount required) was added to the feeding beaker.

In order to correct for any uptake of mercury by the amphipods from the water, a 200-ml sample of water in the feeding exposure beaker was removed by pipet halfway through the exposure period, centrifuged to remove any food particles and the supernatant assayed for ^{203}Hg. Amphipods which had been acclimated with the amphipods used in the feeding experiment, were then added to the supernatant for the same time of exposure as experienced by the feeding group.

At the end of exposure the amphipods were removed from the feeding beaker, using a 5-ml pipet with a tip modified to allow an opening sufficiently large for the passage of amphipods. The amphipods were rinsed by transferral through 3 separate beakers, each containing 150 ml dechlorinated tap water (total time: 30 s). The rinsed amphipods were placed in separate beakers each containing another 150 ml dechlorinated tap water for a period of 6 minutes. At the end of this time individual amphipods were transferred to glass counting vials along with 1 ml of water and then assayed for body content of ^{203}Hg. Each amphipod was then transferred to 2-ℓ beakers containing 1800 ml dechlorinated tap water and maintained there at a density of 2 amphipods per beaker. Measurements of the ^{203}Hg content of each amphipod were taken at post-exposure times of 2, 4, 8, and 24 hours, and then once daily for a maximum of 4 weeks. Water was changed in the clearance beakers each time the amphipods were assayed. Any moults found during clearance were also assayed for their ^{203}Hg content. During the clearance period, amphipods were fed the same diet but uncontaminated with ^{203}Hg. Water temperature during all feeding experiments and subsequent clearance periods was maintained at $19 \pm 1^{\circ}C$ except when the effect of temperature on clearance of CH_3HgCl was being investigated.

Dechlorinated tap water was used in all water uptake experiments, except for the study on the effect of water quality where unfiltered Ottawa River water was also used. Mercury-contaminated water was prepared by adding a measured portion of the stock solution of ^{203}Hg-labelled CH_3HgCl (approximately 4 $\mu\gamma$ Hg ml^{-1}) or $HgCl_2$ (approximately 5 μg Hg ml^{-1}) to a glass beaker containing 1800 ml dechlorinated tap water. The water was stirred for 60 seconds and left to stand for 2 hours before addition of the amphipods.

Throughout the various exposure periods, the concentration and chemical form of mercury in the exposure water was determined as described previously. At the end of the exposure period, amphipods were removed from the contaminated water, rinsed and assayed for their whole body content of ^{203}Hg as described in detail for the feeding experiments.

Data Handling

All individual whole-body measurements of live organisms taken during the post-exposure period after either water or food uptake demonstrated biphasic clearance with a fast-clearing initial phase followed by a much slower phase as illustrated by the results in Figure 1. The data were treated as an exponential curve described by the general equation:

$$y = ae^{-bt}$$

where y is the body burden of ingested mercury, a is compartment size, t is the time, in days of clearance, and b is the fractional clearance rate per day. The biological half life, $t_{1/2}$, or the time required for a half of the accumulated tissue mercury to be lost from the organism as a result of biological processes, was determined by the expression:

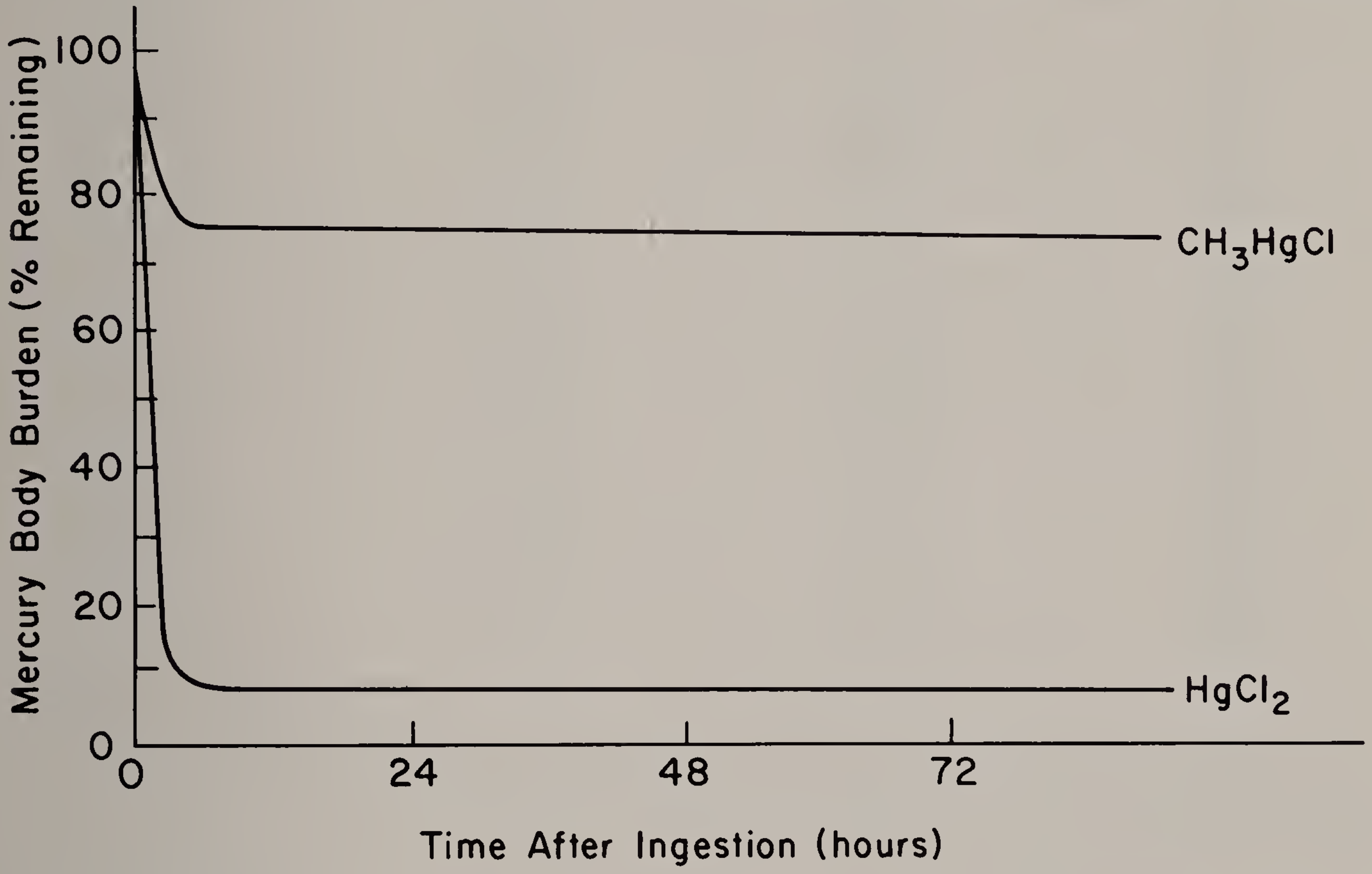

Fig 1. The effect of chemical form of mercury on its assimilation efficiency from the gastrointestinal tract into body tissue of *Hyalella azteca* after ingestion of mercury-contaminated *Scenedesmus* (40 min ingestion period).

$$t_{1/2} = \frac{\ell n2,}{b}$$

with the units being days. Data points were fitted to a straight line by least squares linear regression (Cunningham & Tripp 1973). The results in Table I represent clearance of CH_3HgCl from one amphipod, following a 40-minute period of ingesting $CH_3{}^{203}HgCl$-contaminated *Scenedesmus*. These data are used in the following example calculation of clearance rate and net assimilation efficiency.

The correlation coefficient of the least squares line that best fits the data for the slow-clearing compartment is given by the equation:

$$r = \frac{\Sigma XY - \Sigma X \Sigma Y/n}{[\Sigma X^2 - (\Sigma X)^2/n]\,[\Sigma Y^2 - (\Sigma Y)^2/n]},$$

Table I. Clearance of CH_3HgCl from *Hyalella azteca*[1] following a 40-minute period of ingesting $CH_3{}^{203}HgCl$-contaminated *Scenedesmus.*

Time Post-exposure (h)	Amphipod Body Burden (cpm/organism) Measured cpm	Corrected for Decay[2]	ln Corrected cpm
0.0	465.2	465.2	6.14236
1.2	436.7	436.7	6.07925
2.3	412.2	412.2	6.02151
5.1	412.2	412.2	6.02151
9.6	395.4	395.4	5.9799
24.0	324.3	329.1	5.79636
45.6	335.0	345.0	5.84354
101.4	297.2	315.0	5.75257
148.1	253.2	276.8	5.6233
193.2	272.4	306.5	5.72522
244.3	249.0	288.6	5.66504
289.8	245.6	297.3	5.69474
336.8	211.4	259.7	5.55953
367.3	204.6	259.0	5.55683
439.8	174.6	231.0	5.44242
489.8	187.5	255.6	5.54361

[1] Water temperature during ingestion and clearance was 19±1°C. Specific activity of $CH_3{}^{203}HgCl$ was 2.0×10^5 cpm μg^{-1} Hg.

[2] Using a ^{203}Hg decay half life of 47.2 da.

where X is the post-exposure time in hours and Y is the ln corrected cpm. For this specific example, $r = 0.901$. The slope, b, or fractional clearance rate is calculated using the expression:

$$b = \frac{\Sigma XY - \Sigma X \Sigma Y/n}{\Sigma X^2 - (\Sigma X)^2/n},$$

and is 0.00105 h^{-1} or 0.0252 da^{-1}. $T_{1/2}$ is $\ln 2/0.0252 = 27.5$ da. The size of the slow-clearing compartment given by the y-intercept is defined by the equation:

$$a = \frac{\Sigma Y - b\Sigma X}{n}$$

and is 380.7 cpm. Assimilation efficiency of the ingested CH_3HgCl is defined by the ratio:

$$\frac{a}{c} \times 100$$

where a is the size of the slow-clearing compartment (cpm) and c is the mercury body burden at the end of the exposure period. In this case, assimilation efficiency of CH_3HgCl is $380/465 \times 100 = 81.8\%$. Data for uptake from water and subsequent clearance are treated similarly.

In studying uptake of CH_3HgCl and $HgCl_2$ from water by the amphipod, the term transfer coefficient (T_c), as described by de Freitas and Hart (1975), was used. This unit is defined as the amount of water (g) cleared of its mercury content by 1 g of amphipods in 1 hour. The following is an example of the calculation

Table II. Direct uptake of CH_3HgCl[1] from water by the amphipod *Hyalella azteca.*[2]

^{203}Hg Conc. in Exposure Medium (cpm ml^{-1})	Organism Number	^{203}Hg Content of Organism at 6 min Post-exposure (cpm/organism)	Transfer Coefficient for Uptake	
			Total (Fast- and Slow-clearing Compartments) (h^{-1})	Slow-clearing Compartment[3] (h^{-1})
13000	1	3408	26.2	11.8 (45)
13000	2	3333	25.6	13.1 (51)
13000	3	2796	21.5	8.6 (40)
13000	4	3839	29.5	13.9 (47)
13000	5	2473	19.0	7.4 (39)
13000	6	4108	31.6	16.4 (52)
13000	7	3205	19.0	8.6 (45)
13000	8	1761	13.6	5.6 (41)
		$\bar{x} \pm SE = 3115 \pm 267$		

[1] Specific activity of CH_3HgCl was 2.74×10^6 cpm μg^{-1} Hg, and the level of radioactivity in exposure medium was 13000 cpm ml^{-1} dechlorinated tap water.

[2] Amphipods were exposed for a period of 2 h.

[3] Values in parentheses refer to the size of the slow-clearing compartment relative to the total body burden at 6 min post-exposure.

used to obtain transfer coefficient values for CH_3HgCl from the water to amphipods using the data in Table II.

$$T_c = \frac{3115 \text{ cpm amphipod}^{-1}}{13000 \text{ cpm g}^{-1} \text{ water}} \times 200 \text{ amphipods g}^{-1} \div 2 \text{ h} = 24 \text{ h}^{-1}$$

An amphipod body weight of 5.0 mg (wet weight) was used in calculating transfer coefficient (T_c) values. Note that this transfer coefficient value of 24 h^{-1} is based on the total body burden of mercury acquired during the exposure period. Since mercury clearance is biphasic, as noted previously, the T_c value of 24 h^{-1} includes mercury uptake into the fast-clearing as well as the slow-clearing pool. The fast-clearing pool probably results from surface adsorption desorption processes; whereas the slow-clearing pool is associated with the process of mercury assimilation into amphipod tissue and subsequent excretion. The size of the slow-clearing pool of mercury is obtained from an analysis of the clearance data, similar to the analysis described above for data from mercury-ingestion experiments. The results of this type of analysis, as shown in Table II, demonstrate that uptake into the slow-clearing compartment occurs with transfer coefficient value of 10.8 h^{-1} based on a compartment size of about 45% of the initial total body burden of mercury acquired during the exposure period.

Results and Discussion

Mercury Uptake from Food

Whole-body retention data from amphipods exposed to a single dose of ingested mercury, demonstrated 2-compartment clearance as illustrated in Figure 1. Two-compartment clearance has also been shown for several species of fish by many other workers (Jarvenpaa et al. 1970; Giblin & Massaro 1973; Weisbart 1973; Suzuki & Hatanaka 1975), for the oyster (Cunningham & Tripp 1973), and for the shrimp and polychaete worm (Luoma 1977). With continuously feeding organisms like *Hyalella azteca*, the time of exposure to the contaminated diet is important in determining net assimilation efficiency, as for example, if an ingestion period of longer duration than the gut voidance time is used, erroneously high values will result. Table III shows the results of the experiment to estimate *H. azteca*'s gut clearance time (voidance time). The amphipod's mercury body burden after a 40-minute ingestion period is approximately twice that achieved after a 20-minute ingestion period. However, there is a smaller increase in the amphipod's body burden of mercury from the 40-minute to the 60-minute ingestion period, indicating that somewhere between 40 and 60 minutes of ingestion the amphipod begins to either ingest less or egest a portion of the ingested mercury not absorbed by its gastrointestinal tract. If we assume that the levelling off between 40 and 60 minutes of the mercury body burden does not represent a decrease in ingestion rate, as the amphipods had been starved for several hours before the experiment was performed, then these results demonstrate that the voidance time is $\geq$40 minutes, in general agreement with voidance times reported by Hargrave (1970). Therefore, to measure the entire size of the fast-clearing compartment, and hence net assimilation efficiency, an ingestion period no longer than 40 minutes should be used.

The results presented in Figure 2 also demonstrate that, as exposure time increases, the measured size of the fast-clearing compartment becomes less. After a 40-minute ingestion period, the fast compartment represented 17% of the ingested CH_3HgCl whereas after 24 hours of ingestion, it represented only 11%. This is expected because, as the body burden increases with increasing exposure

Table III. Gut clearance time in *Hyalella azteca* using $CH_3{}^{203}HgCl$-contaminated food.

Time of Exposure to Food (min)	Body Burden of Mercury at end of Exposure Period (cpm/amphipod)*	Number of Amphipods
20	699.3 ± 108.6	4
40	1388.0 ± 143.0	4
60	1481.7 ± 91.9	5

*Specific activity of $CH_3{}^{203}HgCl$ was 5×10^5 cpm μg^{-1} Hg.

time, the proportion of the body burden associated with the gut contents becomes less. On this basis, after 4 to 5 days of continuous exposure to methylmercury, the size of the fast-clearing compartment relative to the total body burden will be undetectable, being about 1 to 2% of the total body burden and hence lost in the scatter of the data.

A typical result for whole-body clearance following a single ingested dose (40 min dosing period) of food contaminated with CH_3HgCl or $HgCl_2$ is illustrated by the results in Figure 2. The initial post-dose series of whole-body measurements defining the fast-clearing (first) compartment coincides with the voidance time of the gastrointestinal tract and represents clearance of that portion of the ingested dose of mercury not absorbed by the intestine. The slow-clearing (second) compartment represents the proportion of the ingested dose that remains associated with body tissues, and thus its size relative to the size of the ingested dose is an effective measure of net assimilation efficiency. As stated earlier, net assimilation efficiency can be calculated by extrapolating the y-intercept of the slow curve back to zero clearance time. In the case of CH_3HgCl, the example clearance curve illustrated in Figure 1 demonstrates that 25% of the ingested dose is

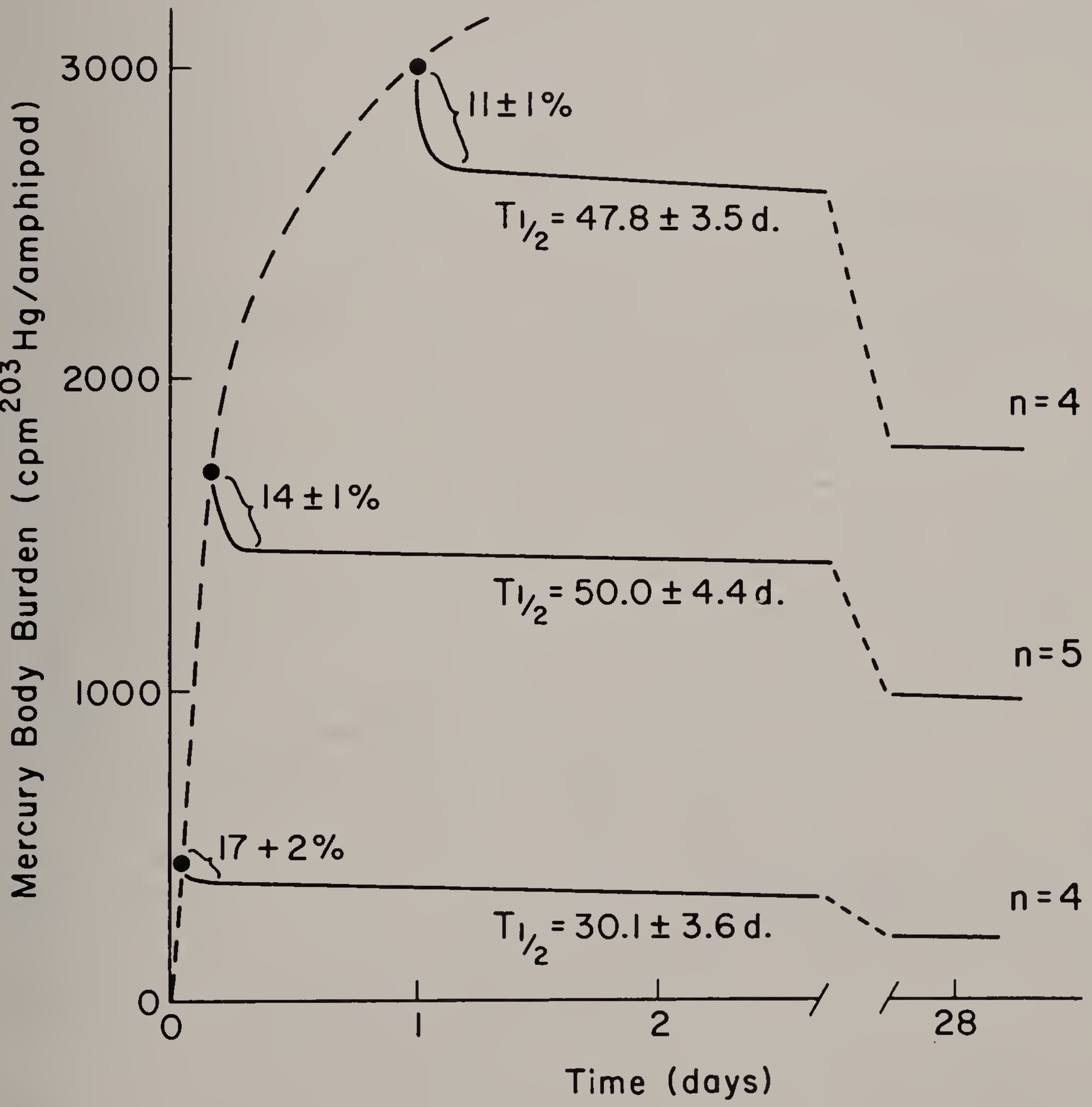

Fig 2. The influence of ingestion period on the apparent assimilation efficiency of CH_3HgCl from the gastrointestinal tract of *Hyalella azteca* and whole-body clearance of CH_3HgCl following ingestion of $CH_3{}^{203}HgCl$-contaminated *Scenedesmus*. Specific activity of $CH_3{}^{203}HgCl$ was 5.9×10^6 cpm μg^{-1} Hg.

rapidly lost and the remaining 75% becomes associated with body tissues and is lost at a very slow rate. Contrastingly, inorganic mercury is assimilated with only about 10% efficiency, as shown in Table IV. These results seem to be independent of food type.

Table IV. Influence of diet composition and chemical form of mercury on mercury assimilation from the gastrointestinal tract of *Hyalella azteca* and subsequent clearance from body tissues.

Food Type[1]	Ingested Mercury[2] (ng Hg/amphipod)		Assimilation Efficiency[2] (%)		$T_{1/2}$ for Slow Compartment (da)	
	CH_3HgCl	$HgCl_2$	CH_3HgCl	$HgCl_2$	CH_3HgCl	$HgCl_2$
Scenedesmus	1.56 ± 0.30(7)[3]	1.44 ± 0.30(11)	77.2 ± 2.4	5.0 ± 0.9	40.8 ± 3.7	6.7 ± 1.4
Navicula	1.88 ± 0.38(5)	1.44 ± 0.30(9)	86.9 ± 1.2	15.1 ± 3.4	50.0 ± 8.5	6.1 ± 1.5
Anabaena	0.68 ± 0.23(4)	6.88 ± 2.15(5)	79.6 ± 3.3	3.3 ± 1.3	55.6 ± 9.0	14.4 ± 3.8

[1] Concentration of methylmercury and inorganic mercury in contaminated foods was 340 and 160 $\mu g\ Hg\ g^{-1}$ dry weight of food, respectively An ingestion period of 40 min was used. The natural levels of mercury (Norstrom & Peters 1972) occurring in the different algal types were $\leq$2% of the levels used in the experiments. Analysis of the mercury content in the methylmercury-contaminated foods by the Westoo procedure (Westoo 1967) demonstrated that $\geq$96% mercury was in the methylmercury form.

[2] Values are given as mean ± SE.

[3] Values in parentheses refer to number of organisms.

Similar assimilation efficiencies for CH_3HgCl and $HgCl_2$ have been shown using many other species of animals: man (Miettinen et al. 1971), fish (Hannerz 1968; Matida et al. 1971, de Freitas et al. 1974), and aquatic invertebrates (Miettinen et al. 1971; Huckabee et al. 1975). The amount of mercury taken up from water during ingestion of mercury-contaminated food accounts for only a very small (3% or less) proportion of the body burden acquired during the ingestion period, as shown by the results in Table V. This can be considered a relatively insignificant error, but it should be noted that a correction for this error in estimating the amount of ingested mercury has not been applied to the data.

The results in Figure 3 on the effect of feeding rate on assimilation efficiency of CH_3HgCl-contaminated *Scenedesmus* and *Anabaena* demonstrate that with both foods there was an increase of about 10% in the assimilation efficiency of mercury with feeding rate ranging from 1 to approximately 14 μg food (dry weight)/hour/amphipod. These feeding rates are moderate compared to ingestion rates of 30 μg sediment/hour/amphipod and 25 μg bacteria/hour/amphipod (Hargrave 1970a; b). It is probable that as ingestion rate increases, so does the residence time of the larger food mass in the gut. The longer residence time may allow more complete digestion of mercury as well as ingested calories, as suggested by Huckabee (Huckabee et al. 1975). In the case of $HgCl_2$-contaminated foods, the assimilation efficiencies reported in Table IV were so low that even if they were affected by feeding rates, we were unable to detect an effect.

Results presented in Table VI on the fractionation of the mercury remaining in amphipod tissue after a post-exposure period of 28 days showed that the chemical form of mercury remains unchanged during ingestion and subsequent tissue retention. This agrees with several studies by Jernelov (1968; 1972), Pennacchioni et al. (1976) and Pentreath (1976). In contrast to this, Guarino et al.

Table V. Direct uptake from water of CH_3HgCl and $HgCl_2$ during ingestion of mercury-contaminated food by *Hyalella azteca*, due to leaching of mercury from the food.

Chemical Form of Mercury	Food Type	Total Uptake from Food and Water (40 min exposure) (cpm/amphipod)	Direct Uptake from Water[1] (40 min exposure) (cpm/amphipod)	Error due to Direct Uptake from Water (%)
CH_3HgCl[2]	*Scenedesmus*	310.0 ± 60.2(7)[4]	3.0 ± 2.0(3)	1.0
	Anabaena	131.3 ± 45.0(9)	8.0 ± 4.7(3)	6.1
	Navicula	334.7 ± 70.4(11)	8.0 ± 3.0(2)	2.4
$HgCl_2$[3]	*Scenedesmus*	3510.0 ± 804.9(15)	29.0 ± 2.7(4)	0.8
	Anabaena	14800.0±3954.3(7)	383.0±287.3(2)	2.6
	Navicula	3560.0 ± 902.9(9)	96.0 ± 10.5(2)	2.7

[1] Amphipods were exposed for 40 min to filtered water samples removed from the beakers containing ^{203}Hg-contaminated foods.

[2] Specific activity of $CH_3{}^{203}HgCl_2$ was 1.92×10^6 cpm μg^{-1} Hg.

[3] Specific activity of $^{203}HgCl_2$ was 2.7×10^6 cpm μg^{-1} Hg.

[4] All values represent the mean ± SE; values in parentheses refer to the number of organisms.

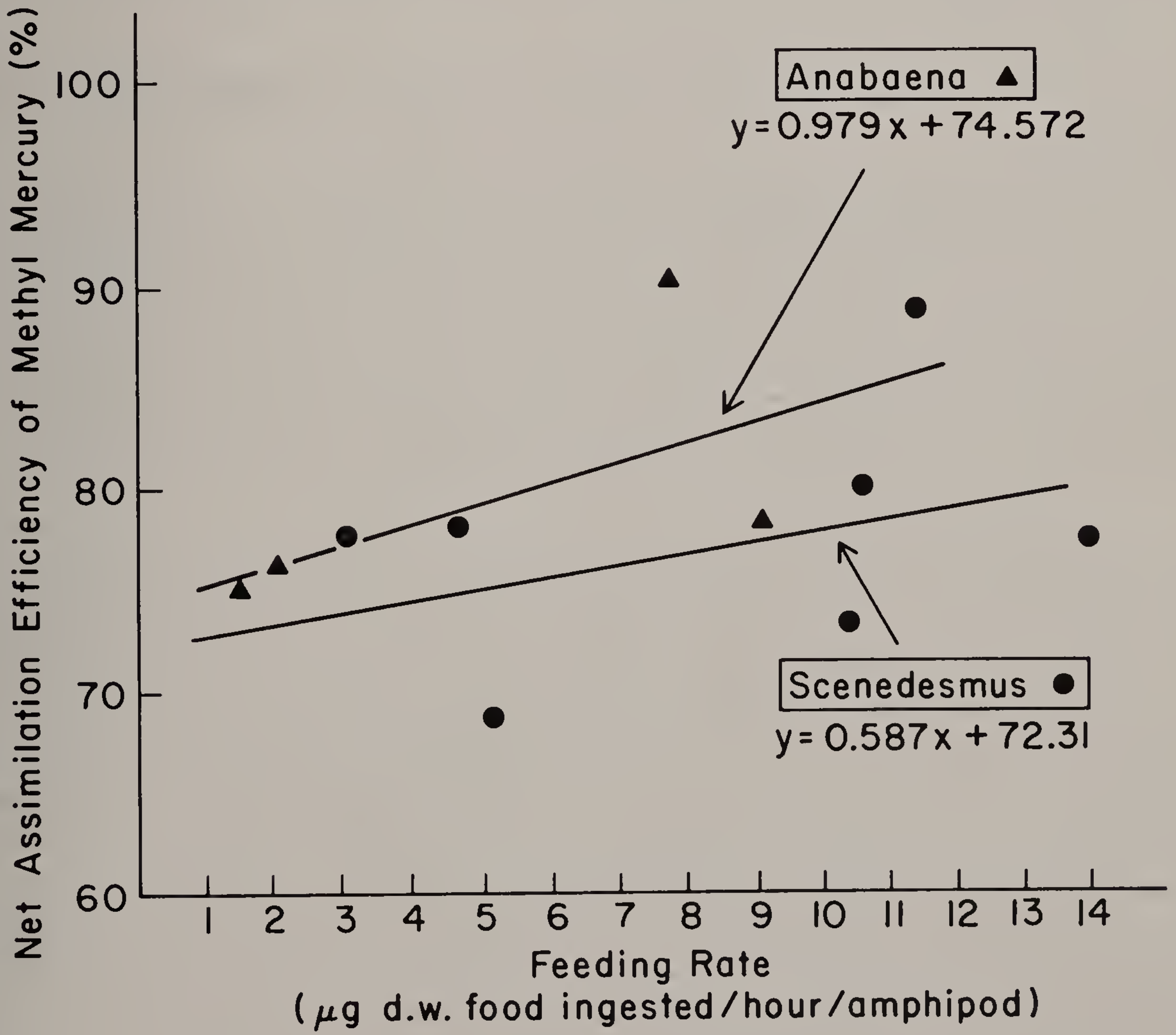

Fig 3. Effect of feeding rate and type of food on assimilation efficiency of CH_3HgCl from the gastrointestinal tract of *Hyalella azteca*.

Table VI. Mercury concentration in water and its chemical stability during exposure of *Hyalella azteca.*[1]

Chemical Form of Mercury	Duration of Exposure (h)	Mercury Concentration in Water (μg Hg ml^{-1})	Mercury Loss from Water during Uptake by Amphipods (%)	Mercury Composition	
				% organic	% inorganic
CH_3HgCl[2]	0	9.04×10^{-4}	0	98	
	8	8.96×10^{-4}	0.8 (5%)[4]	90	
	24	8.78×10^{-4}	2.9 (10%)	93	
	28	8.48×10^{-4}	6.2 (10%)	83	
$HgCl_2$[3]	0	6.09×10^{-3}	0		91.3
	4	5.94×10^{-3}	2.5 (10%)		89.8
	8	5.57×10^{-3}	8.5 (13%)		—
	24	4.86×10^{-3}	20.2 (40%)		87.8

[1] An average density of 5 amphipods 100 ml^{-1}.

[2] Specific activity of $CH_3{}^{203}HgCl$ was 1.06×10^6 cpm μg^{-1} Hg.

[3] Specific activity of $^{203}HgCl_2$ was 1.66×10^6 cpm μg^{-1} Hg.

[4] Values in parentheses show mercury loss from water in absence of amphipods. These results were obtained at CH_3HgCl conc. of 4.2×10^{-3} μg Hg ml^{-1} and $HgCl_2$ conc. of 2.3×10^{-3} μg Hg ml^{-1}, at 24°C in dechlorinated tap water (D.C. Mortimer, in verb.).

(1976) reported biotransformation rates $\leq$ 3%/day in lobsters and as high as 6%/day in rats.

The clearance times for both CH_3HgCl and $HgCl_2$ after consuming mercury-contaminated foods are reported in Table IV. The half life of CH_3HgCl ranged from 40 to 55 days. In contrast, $HgCl_2$ was cleared much more rapidly with a $t_{1/2}$ of only 6 to 14 days. These results agree with other studies showing that CH_3HgCl is excreted more slowly than $HgCl_2$ (Berlin & Ulberg 1963; Jarvenpaa et al. 1970; Smith et al. 1975). Clearance time of $HgCl_2$ has been found to be 25 days for crabs (Sloan et al. 1974) and 5 to 10 days for molluscs (Unlu et al. 1972).

Mercury Uptake from Water

The maintenance of essentially steady state conditions with respect to both organic and inorganic mercury concentration in perfusate solution during an exposure period of 2 hours is shown by the data in Table VI. The observed reduction in the mercury concentration of only 2 to 3% after 24 hours in the case of CH_3HgCl was in sharp contrast to the much greater concentration reduction of approximately 20% after 24 hours in the case of $HgCl_2$. This loss does not result from uptake by the amphipods. It can be observed in the absence of organisms as reported by Newton and Ellis (1974), who found that substantial amounts of $HgCl_2$ were lost at a concentration of 0.2 mg Hg ℓ^{-1} and lower, and Dokiya et al. (1974), who also showed similar results. The results in Table VI also demonstrate that no significant methylation or demethylation of mercury in the exposure medium occurred during the exposure period.

The results in Table VII illustrate that the transfer coefficient (T_c) of about 12 h^{-1} for CH_3HgCl was independent of concentration over a 20-fold range. Studies

Table VII. Effect of concentration of CH_3HgCl_1 and $HgCl_2$ on uptake from dechlorinated water by *Hyalella azteca.*[1]

Chemical Form of Mercury	*Mercury Concentration in Exposure Medium* (*cpm ml*$^{-1}$)	(µg Hg ml^{-1})	*Number of Amphipods*	*Uptake Rate* (µg Hg/amphipod h^{-1})	*Transfer Coefficient*[4] T_c (h^{-1})
CH_3HgCl[2]	2170	0.0008	10	0.88 x 10^{-4}	13.3±1.9
	17317	0.0060	10	4.26 x 10^{-4}	11.9±1.3
	40462	0.0140	9	15.99 x 10^{-4}	12.0±1.1
$HgCl_2$[3]	748	0.0005	8	0.42 x 10^{-4}	11.2±2.0
	7267	0.0050	6	3.45 x 10^{-4}	10.1±1.3
	76760	0.0500	7	26.00 x 10^{-4}	5.9±0.8

[1] Amphipods were exposed for 2 h at a water temperature of 19±1 °C.

[2] Specific activity of $CH_3{}^{203}HgCl$ was $2.9x10^6$ cpm μg^{-1} Hg.

[3] Specific activity of $^{203}HgCl_2$ was $1.5x10^6$ cpm μg^{-1} Hg.

[4] Transfer coefficient values represent the weight of water, in grams, completely cleared of its mercury content by 1 g wet wt of amphipods in 1 h. Each value represents the mean ± SE.

with fish of the same weight class also showed T_c to be indpendent of mercury concentration (de Freitas et al. 1974; de Freitas & Hart 1975). For 2-g fish (*Notemigonus crysoleucus*), T_c values were about 4 h^{-1} at methylmercury concentrations ranging from $1x10^{-5}$ µg Hg ml^{-1} to $1x10^{-3}$ µg Hg ml^{-1} (de Freitas et al. 1977). For $HgCl_2$, over a concentration range of $5x10^{-4}$ µg Hg ml^{-1} to $5x10^{-3}$ µg Hg ml^{-1}, T_c values for amphipods were similar at 11.2 and 10.1 h^{-1} respectively, but when the concentration of $HgCl_2$ was as high as $5x10^{-2}$ µg Hg ml^{-1} the value of the transfer coefficient dropped to 5.9 h^{-1}.

The concentration range, $1x10^{-4}$ to $1x10^{-3}$ µg Hg ml^{-1}, is realistic for many contaminated waters (Norstom et al. 1976). A concentration of $5x10^{-3}$ µg Hg ml^{-1} represents an extremely polluted enviornment (Gavis & Ferguson 1972). However, a $HgCl_2$ concentration of $5x10^{-2}$ µg Hg ml^{-1} is unrealistic for the natural environment and would likely be lethal to organisms exposed over a long period of time (Barnes & Stanburg 1948; Wisely & Blick 1967; Ray & Tripp 1976).

Direct uptake of chemicals from water involves a number of adsorption sites probably located over the amphipod's general integument, but uptake of mercury, particularly CH_3HgCl, into tissues may occur predominantly through the branchia, as was found with uptake of PCBs (Wildish & Zitko 1971). These authors also found uptake to be unaffected by the amphipod's stage of intermoult. Molts collected during the post-exposure clearance period did not contain significant amounts of ^{203}Hg, nor was there any detectable decrease in the body burden of ^{203}Hg as a result of molting. Mercury uptake due to drinking contaminated water should not be an important uptake vector as the drinking rate of *Gammarus duebeni*, for example, is less than 1 µl h^{-1} (Lockwood & Andrews 1969), and at a methylmercury concentration of $8x10^{-4}$ µg ml^{-1} the resulting uptake rate would only be $8x10^{-7}$ µg Hg/amphipod h^{-1} at a drinking rate of 1 µl h^{-1}, extremely small compared to the observed uptake rate of $4x10^{-5}$ µg Hg/amphipod h^{-1} as reported in Table VII.

Table VIII. Effect of temperature on uptake of CH_3HgCl from dechlorinated tap water by *Hyalella azteca*.[1]

CH_3HgCl[2] Concentration in Water (μg Hg ml^{-1})	Water Temperature (°C)	Number of Amphipods	Total Uptake Rate (μg Hg/amphipod h^{-1})	Transfer Coefficient[4] into Slow-clearing Compartment (h^{-1})
0.047	20	8	5.88×10^{-3}	10.8 ± 1.0
0.053	10	8	3.31×10^{-3}	6.7 ± 0.9
0.045	5	9	1.71×10^{-3}	3.5 ± 0.6

[1] Amphipods were exposed for 2 h.

[2] Specific activity of $CH_3{}^{203}HgCl$ was 2.74×10^6 cpm μg^{-1} Hg.

[3] Acclimation of organisms was achieved by a 1°C da^{-1} drop in aquarium temperature, followed by a holding period of 1 wk prior to testing.

[4] Transfer coefficient values represent the weight of water, in grams, completely cleared of its mercury content by 1 g of amphipods in 1 h. Each value represents the mean ± SE.

Our results on the effect of temperature on uptake from water presented in Table VIII, show that the transfer coefficient decreased from about 11 h^{-1} to 4 h^{-1} at 20°C and 5°C respectively. These results suggest that uptake is directly related to metabolic rate of the amphipod. Similar results on the effect of temperature have been reported for *Daphnia magna* (Huckabee et al. 1975; Trudel 1980), various species of fish (Murphy & Murphy 1971; MacLeod & Pessah 1973; Reinert et al. 1974; Ruohtula & Miettinen 1975; de Freitas et al. 1977) and mollusks (Pringle et al. 1968). However, Smith (Smith et al. 1975) concluded that temperature had no effect on direct uptake of mercury from water by clams. This conclusion may not be valid, as exposure of clams to a food-free medium results in a marked reduction in their filtration rate and a consequent reduction in uptake rate would be expected.

In the present study, 2 sources of water were used: dechlorinated tap water and unfiltered Ottawa River surface water. For both CH_3HgCl and $HgCl_2$, the transfer coefficient for mercury from water to the amphipod was lower in the unfiltered river water (Table IX). The importance of water quality on mercury bioaccumulation is well documented (Johnels et al. 1967; Nuorteva & Hasanen 1971; Karbe et al. 1975), but the type of field data reported in these studies cannot be used to distinguish between food and water vectors or clearance. Results from laboratory studies on fish (deFreitas 1977) show an enhancement of 2- to 3-fold in assimilation efficiency of methylmercury from Ottawa River water depending on season. Also, using filtered river water, the transfer coefficient from water to fish for methylmercury was increased by 40% compared to unfiltered water, similar to our present results with amphipods, as presented in Table IX. As applied to natural systems, our results suggest that transfer coefficient values can be assumed to fall in the range of 2.5 h^{-1} to 7 h^{-1} for CH_3HgCl and about 50% lower for $HgCl_2$ as shown in Table IX. Transfer coefficient values probably fluctuate to an even greater extent in natural environments due to the combined effects of seasonal changes in water quality parameters and temperature related changes in metabolic rate.

Table IX. Effect of water quality on direct uptake of CH_3HgCl and $HgC1_2$ from water by *Hyalella azteca.*[1]

Water Type	Chemical Form of Mercury	Mercury Concentration in Exposure Medium (μg Hg ml^{-1})	Number of Amphipods	Total Uptake Rate (μg Hg/amphipod h^{-1})	Transfer Coefficient[4] T_C (h^{-1})
Dechlorinated tap water	CH_3HgCl[2]	0.0003	8	$7.0x10^{-5}$	21.7 ± 1.6
Ottawa River water		0.0005	8	$4.0x10^{-5}$	6.8 ± 0.9
Dechlorinated tap water	CH_3HgCl	0.0580	10	$1.4x10^{-3}$	2.4 ± 0.5
Ottawa River water		0.0350	9	$0.6x10^{-3}$	1.5 ± 0.3
Dechlorinated tap water	$HgCl_2$[3]	0.0060	8	$8.0x10^{-4}$	11.1 ± 1.2
Ottawa River water		0.0070	10	$3.0x10^{-4}$	3.9 ± 0.5
Dechlorinated tap water	$HgCl_2$	0.3300	8	$1.0x10^{-2}$	2.8 ± 0.1
Ottawa River water		0.3700	8	$0.6x10^{-2}$	1.5 ± 0.4

[1] Amphipods were exposed for 2 h at a water temperature of 19±1°C.
[2] Specific activity of $CH_3{}^{203}HgCl$ was $2.16x10^6$ cpm μg^{-1} Hg.
[3] Specific activity of $^{203}HgCl_2$ was $1.8x10^6$ cpm μg^{-1} Hg.
[4] Transfer coefficient values represent the weight of water in grams, completely cleared of its mercury content by 1 g of amphipods in 1 h. Each value represents the mean ±SE.

It should be noted that our results in uptake from water and release of mercury by *Hyalella azteca* are in general agreement with corresponding values for *Daphnia magna* and various fish species, when differences in body weight are taken into account as shown for fish by deFreitas and Hart (1975). For example, transfer coefficient values, using CH_3HgCl, for *D. magna* (wet weight 0.1 mg) range from 100 to 300 h^{-1} (Huckabee et al. 1975; Trudel 1979). *Hyalella azteca* (wet weight 5.0 mg) has T_c values ranging from 8 to 25 h^{-1}. Studies on fish, *Notemigonus crysoleucus* and *Catostomus commensoni*, show T_c values of 4.4 h^{-1} for a 2-g fish, 3.0 h^{-1} for a 10-g fish and 1.7 h^{-1} for a 100-g fish (de Freitas 1977).

The efficiency of mercury uptake from water can be usefully compared to oxygen uptake by organisms (de Freitas 1974: Norstrom et al. 1976). Assuming oxygen uptake from water to be 100% efficient and an oxygen concentration of 9 μg ml^{-1} water, then *Hyalella* would remove the oxygen from 133 ml water/g amphipod h^{-1} (a T_c for 0_2 of 133 h^{-1}). With a transfer coefficient value for methylmercury of 20 h^{-1} (20 ml water/g wet weight h^{-1}), uptake of mercury from water would be 15% (20/133) as efficient as oxygen uptake. This value agrees with other studies as reviewed by Norstrom et al. (1976), and more recently by de Freitas (1977) and Phillips and Buhler (1978) who found mercury uptake by fish to be 15 to 30% as efficient as oxygen uptake.

Our results quantitatively define the bioaccumulation potential of both methylmercury and inorganic mercury in terms of three parameters: (1) efficiency of uptake from food, (2) efficiency of uptake from water and (3) elimination or fractional clearance from the whole body. The following discussion illustrates the use of these results in predicting the probable magnitude of mercury uptake via the food and water vectors in a natural environment like the Ottawa River.

The magnitude of the water vector and food vector can be calculated as follows: at a methylmercury concentration in water of 5 ng Hg ℓ^{-1} (20% of total Hg concentration in water of 25 ng ℓ^{-1}) and a T_c value of 20 h^{-1}, *Hyalella azteca* would accumulate 2.4 ng methylmercury/g amphipod da^{-1} by direct uptake from water. The concentration of total mercury in sediments from shallow areas of the Ottawa River in 1976 was 0.024 μg Hg g^{-1} (wet weight of sediment), of which 0.0024 μg Hg g^{-1} was proabably methylmercury (Miller et al. 1977). At an ingestion rate of 0.003 g wet weight of sediment/hour/amphipod (50% body wt/da) and an assimilation efficiency from the gastrointestinal tract of ∼0.8, uptake of methylmercury via the food vector should be ∼1.0 ng Hg/g amphipod da^{-1}. Under these conditions, the food vector would account for considerably less than 50% of the total uptake of methylmercury, ∼3.4 ng Hg/amphipod da^{-1}. A continuous uptake of methylmercury at a constant rate of ∼3.4 ng Hg/g amphipod da^{-1} (value for food and water uptake) will equal loss rate from the organism when its mercury body burden is ∼230 ng Hg/g amphipod based on a fractional clearance rate of methylmercury from body tissues of 1.5% per day. This means that the concentration of methylmercury in *H. azteca* should approach an equilibrium value of about 0.23 μg Hg g^{-1} wet weight of tissue after about 4 months of exposure.

Corresponding calculations for uptake of inorganic mercury result in water and food vectors of about 5 ng Hg and 1 ng Hg/g organism/day respectively. Inorganic mercury is cleared from body tissues at about 4%/day, a much faster rate than methylmercury, and the concentration of inorganic mercury in *Hyalella azteca* should approach an equilibrium value of about 150 ng Hg g^{-1} amphipod after about 2 months of exposure.

These calculations do not take into account growth during this period. Mercury body burdens in amphipods would thus be somewhat lower than calculated above, owing to growth dilution. Table X shows actual field values for the mercury content in amphipods and other benthic invertebrates on a ppm dry-weight basis. The above predictions agree quite well with these field samples. It should be noted that the values for methylmercury in water and sediments used in the above example are close to levels observed in the Ottawa River and many other areas of Canada (Miller et al. 1977). It should also be stressed that this simple treatment of the uptake process can be used to distinguish between food and water uptake only when the concentration of mercury in the water or diet is known. The amphipod example used here demonstrates that the water vector is probably of equal or greater magnitude than the food vector, particularly in areas with low "background-type" contamination levels. One can speculate that the relative magnitude of the water vector will decrease during periods of decreasing mercury pollution and conversely, in areas of increasing pollution, the relative magnitude of the water vector will increase. If the water vector does in fact account for 50% or more of the mercury taken up by *Hyalella azteca*, then the hypothesis that biological magnification in aquatic environments is controlled by mass transfer of trace substances through the food web may have only limited application to the problem of high mercury levels in aquatic organisms. However, some degree of biomagnification in the benthic food web is virtually

Table X. Levels of total mercury in amphipods and other benthic invertebrates found in their natural environment.

Mercury Concentration (μg Hg g^{-1} dry wt.)	Location of Amphipod Collection	Date	Reference
2.16	Kettle Island Bay, Ottawa River	April 1977	Present study
2.75		July 1977	
0.29	Upstream, Upper Duck Island Ottawa River	June 1976	Miller et al. 1976
25.00	Downstream, Upper Duck Island	July 1976	
5.22	Lake Temiscaming, Quebec	May 1976	
0.05 - 0.07[1]	above mill, Sweden		Johnels et al. (1976)[1]
1.90 - 17.0	below mill, Sweden		

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[1] This study does not specify the species of benthic invertebrates studied.

assured in the transfer of methylmercury from prey to predator, solely on the basis of its high assimilation efficiency of 80%, even in the case of a rapidly growing predator in which 10-20% of ingested calories are deposited as new tissue. In this context, it is obvious that a food conversion efficiency for growth of 10%, for example, precludes the food-chain biomagnification of any compound including inorganic mercury whose assimilation efficiency is ≤10%, regardless of how slowly it is eliminated from body tissues.

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ROLE OF KREBS CYCLE ACIDS IN PROMOTING ERGOT ALKALOID PRODUCTION BY CLAVICEPS SPECIES

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In further efforts to account for the marked stimulation of alkaloid production by *Claviceps* when Krebs cycle acids are included in the nutrient medium, the ability of *Claviceps* strains to take up and metabolize these compounds was examined. Marked differences were found in the capacity of different strains to grow on carboxylic acids as sole sources of carbon. *Claviceps* strain PRL 1980, which could grow on succinate and fumarate but not on citrate, malate, acetate, or α-ketoglutarate, nevertheless responded with similar increases in aklaloid yield when any of the Krebs cycle acids was added to a production medium. All of these acids were taken up by the fungus mycelium, but only succinate and fumarate achieved intracellular concentrations exceeding those in the uptake solution. Examination of uptake characteristics indicated that the acids entered the mycelium by passive diffusion with differences in rate and duration being markedly influenced by subsequent metabolism. A study of succinate uptake showed that entry of the monoanion was accompanied by influx of 3 potassium ions and efflux of 2 hydrogen ions, suggesting that cation transport, supported by metabolism, may be important in establishing the conditions for prolonged uptake of Krebs cycle acids.

Afin d'expliquer la stimulation prononcée de la production d'alcaloides par *Claviceps* quand on introduit dans son milieu de culture les acides du Cycle de Krebs, on a examiné la capacité de diverses souches de *Claviceps* d'absorber et de métaboliser ces acides. Il y a des différences prononcées entre les taux de croissance des diverses souches lorsque les acides carboxyliques sont leur unique source de carbone. *Claviceps,* souche PRL 1980, peut croitre avec du succinate ou du fumarate comme unique source de carbone mais pas avec du citrate, du malate, de l'acétate ou de l'alpha-cétoglutarate; néanmoins sa production d'alcaloides est accrue de façon égale lorsque n'importe quel acide du Cycle de Krebs est ajouté à son milieu de production. Tous ces acides sont absorbés par le mycélium de champignon, mais seuls le succinate et le fumarate se retrouvent intracellulairement à des concentrations supérieures à celle de la solution d'absorption. L'examen des caractéristiques de l'absorption a indiqué que l'entrée des acides dans le mycélium se fait par diffusion passive et que les différences de taux et de curée d'entrée sont causées par le métabolisme subséquent. Une étude de l'absorption du succinate a montré que l'entrée de ce mono-anion est accompagnée par l'influx de 3 ions potassium et par la sortie de 2 ions hydrogène, ce qui indique que le transport des cations, lui-même supporté par le métabolisme, peut être important pour l'instauration des conditions nécessaires à une absorption prolongée des acides du Cycle de Krebs.

Introduction

To obtain an optimum yield of ergot alkaloids in cultures of *Claviceps,* large amounts of ammonium succinate, citrate, fumarate, or malate are usually included in the medium (Taber 1967). The beneficial effect of these Krebs cycle acids is not solely one of pH control (Brar et al. 1968) and studies on their utilization have been directed toward understanding the physiological responses that favor alkaloid biosynthesis (Taber 1968; 1971; 1973; 1976). *Claviceps* strain

PRL 1980 can metabolize ammonium [^{14}C]succinate to a wide range of cell constitutents and in acidic media grows well with succinate as the only source of carbon. A glucose supplement is needed for growth at pH 7, implicating succinate uptake as a limiting factor under alkaline conditions. The effect of pH on uptake has been confirmed by permeability studies with [^{14}C]succinate. The response to pH is bimodal; it is low at pH 7 and reaches a peak near pH 5 where the concentration of succinate monoanion is at a maximum. The second peak occurs at very low pH values and matches the increasing concentration of undissociated acid. Most studies have centered on uptake of succinate near the pH 5 optimum.

Claviceps strain PRL 1980 differs from several bacteria where transport of Krebs cycle acids has been studied in that uptake occurs without induction and is not catabolite-repressed by glucose (Villarreal-Moguel & Ruiz-Herrera 1967; Kay & Kornberg 1971; Postma & van Dam 1971; Willecke & Pardee 1971; Fournier et al. 1972; Wilkerson & Eagon 1972). Uptake of succinate from solutions similar in concentration to those used in alkaloid production media exhibits an initial rapid component which is insensitive to metabolic inhibitors (Taber 1971). Superimposed on this is a slower, concentration-dependent and inhibitor-sensitive permeation. The combined process equalizes the intracellular and extracellular concentrations within approximately 12 minutes. Up to 85% of the radioactivity can be recovered from the mycelium as succinic acid at this time (Taber 1973). The rate of uptake during the inhibitor-sensitive phase is appreciably higher if the mycelium has been grown in a medium containing ammonium succinate.

These experiments suggest that succinate diffuses into the cell as a result of the concentration gradient. Whether or not diffusion is facilitated by a carrier has not been unequivocally determined but there is no strong evidence of active transport. Uptake of succinate in excess of that equalizing the intracellular and extracellular concentrations can be attributed to metabolic drag. We report here additional experiments bearing on this question. Earlier studies on the inhibition of succinate uptake by other Krebs cycle acids suggested that these compounds might compete for a common permeation process (Taber 1971). Because of the value of this information in establishing the uptake mechanism, as well as in clarifying the role of Krebs cycle acids in the physiology of alkaloid production, we have reexamined both the uptake of citric, fumaric, malic, and α-ketoglutaric acids by *Claviceps* strain PRL 1980 and the ability of these substances to support growth and alkaloid production. To assess whether the ability to use such compounds as sole carbon sources for growth is widely distributed in *Claviceps,* we have also surveyed additional strains.

Materials and Methods

Cultures

Claviceps strain PRL 1980 was isolated from *Pennisetum typhoides* and is probably *Claviceps fusiformis* (Loveless 1967). Strains PRL 1565, 1578, and 1598 are isolates of *Claviceps purpurea* (Taber & Vining 1960) and strain Ta 1 is an isolate of *Claviceps paspali* (Brar et al. 1968).

Media

Medium T-4M, a modification of medium T-4 (Taber 1973), was used to grow mycelium for measuring uptake of organic acids. It contained (gl^{-1}): D-glucose (autoclaved separately), 10; NH_4NO_3, 0.8; KH_2PO_4, 1.6; K_2HPO_4, 2.4; $MgSO_4{\cdot}7H_2O$, 0.3; and the following micronutrients (mgl^{-1}): $FeSO_4{\cdot}7H_20$, 10; $ZnSO_4{\cdot}7H_20$, 4.4; $CaCl_2{\cdot}2H_2O$, 6.0; $CuCl_2{\cdot}2H_20$, 0.03; $CoCl_2{\cdot}2H_2O$, 0.02; $MnSO_4{\cdot}H_2O$, 3.0; NaCl, 2.5; $(NH_4)_6Mo_7O_{24}{\cdot}4H_2O$, 1.8, and biotin, 0.05.

Medium 10-B-2 (Taber 1967), and modifications with succinic acid replaced by another organic acid at equimolar concentrations, was used to produce ergot alkaloids. It contained (gℓ^{-1}): mannitol, 50; succinic acid, 7.2; KH_2PO_4, 0.25; $MgSO_4.7H_20$, 0.3 and the same micronutrients as medium T-4M except that cobalt chloride was omitted, and ferrous sulphate was used at half concentration. The pH was adjusted to 5.2 with ammonia. Media containing α-ketoglutaric acid and acetic acid were sterilized by filtration.

Medium T-6, used to measure growth on organic-acid carbon sources, contained (gℓ^{-1}): carbon from organic acid, 4.07; NH_4NO_3, 0.8; KH_2PO_4, 3; $MgSO_4 \cdot 7H_20$, 0.3 and the same micronutrients as medium T-4M. Half of each batch of medium was adjusted to pH 6.8-7.0 with KOH; the other half was adjusted to pH 4.0-4.1 and the amount of potassium equalized by adding KCl.

Uptake Experiments

Uptake solutions contained a ^{14}C-labeled organic acid at the specified concentration in 90 ml of 30 mM potassium phosphate buffer, pH 4.0-4.1 or 6.8-7.1. In testing the effect of phosphate, the buffer salts were omitted; the pH was adjusted with KOH and the potassium content was brought to equivalency with KCl. Each uptake solution contained 12.5 μCi of radioactivity. Of the compounds used, [2,3-^{14}C]succinic acid was obtained from New England Nuclear Corporation, Boston, Massachusetts; α-keto-(5-^{14}C)glutaric acid, (1,5-^{14}C)citric acid, L-(U-^{14}C)malic acid and (2,3-^{14}C)fumaric acid were obtained from Amersham/Searle, Des Plaines, Illinois. The radiochemical purity of each compound was verified by paper chromatography followed by scanning with a Packard model 7201 radiochromatogram scanner.

The mycelium used in uptake studies was collected by centrifugation from 4 125-ml Erlenmeyer flask cultures incubated with shaking for 24 hours in medium T-4M after receiving 10 ml of homogenized inoculum (Taber & Vining 1959). It was washed 4 times with either phosphate buffer or water (the latter only when determining the effect of phosphate on uptake) of the same temperature as that of the uptake mixture. About 3 ml of the fourth wash was left behind to ensure that cell water was not drawn out of the mycelium during decantation. Approximately 36 ml of washed mycelium, formed as a paste with the 3 ml of water or buffer, was added to each uptake solution. The amount added was approximately 6 mg per ml and was measured in each experiment.

The uptake mixture was aerated at a rate of 1 volume of air per volume of mixture per minute. At intervals, samples of approximately 3 ml were withdrawn into a large-bore pipet and discharged on to a course sintered glass filter under suction. The mycelium was quickly washed with 7 ml of buffer (or water when appropriate), freeze-dried, heated to 100° C for 15 minutes and stored in a desiccator for combustion as described by Taber (1976). In experiments where CO_2 was collected, the air stream from the uptake mixture after final addition of sulfuric acid was vented into 0.25 N NaOH. One gram of dried mycelium was considered to represent 4 ml of cell water (Benko et al. 1967).

Uptake and efflux of sodium and potassium ions were measured in an unbuffered reaction mixture containing 41 mM succinic acid (adjusted to pH 4 with KOH) after 1 and 15 minutes contact with mycelium that had been previously washed 4 times with distilled water. Amounts of mycelium equivalent to 747 mg dry weight were added to the succinic acid solution and to an equal volume of distilled water which served as the control. The temperature of the incubation mixtures was 24°C. Sodium and potassium were measured with a Perkin Elmer model 2903 atomic absorption spectrophotometer.

Other Procedures

Cultures testing ergot alkaloid production were grown with shaking in 33 ml of medium contained in 125-ml Erlenmeyer flasks and were harvested by freeze-drying. The residual solids, basified with aqueous ammonia, were extracted with diethyl ether. Alkaloids were transferred from the ether into 0.2 N H_2SO_4 and reacted with van Urk reagent (Vining & Taber 1959). Alkaloid content was expressed as ergometrine equivalents.

Growth was estimated as the weight of mycelium collected by filtration, washed with water and dried at 95°C for 24 hours. To examine uptake mixtures for sugars and amino acids, filtered samples were acidified and extracted with ether to remove succinic acid, freeze-dried and subjected to paper chromatography (Taber 1973). The amount of unchanged [2,3-^{14}C]succinic acid accumulated in the mycelium was estimated from the radioactivity extracted by ether (Taber 1976). Radioactivity in samples of the initial uptake solution and of mycelium was measured, after combustion to carbon dioxide and collection as barium carbonate, with a Nuclear Chicago model 1152 low-background gas-flow counter.

Results

Growth on Krebs Cycle Acids

Claviceps strains differed in their ability to grow in media containing a carboxylic acid as the sole source of carbon (Table I). The variation was not due solely to species differences since the three strains (PRL 1565, PRL 1578, & PRL 1598) of *Claviceps purpurea* showed a wide range of tolerance. In general, growth

Table I. Growth ($g\ell^{-1}$) of *Claviceps* strains on organic acids as sole carbon sources.*

Strain	Initial pH	Acetate	Citrate	α-Keto glutarate	Succinate	Fumarate	Malate
PRL 1980	4	0	0	0	1.6	0.8	0
	7	0	0	0	0	0.4	0
PRL 1598	4	0	2.3	2.3	2.3	2.3	2.3
	7	2.8	2.9	1.0	2.7	2.5	2.3
PRL 1565	4	0	0	0	2.7	1.4	0.28
	7	0	0	0.4	0	0.4	0.1
PRL 1578	4	0	0	0	1.0	0.7	0
	7	0	0	0	0	0.5	0.5
Ta1	4	0	0	0.3	3.6	1.1	0.35
	7	0	0	0	0	0.4	0.16

*Cultures were incubated stationary in medium T-6 at 24°C. Strain PRL 1578 was harvested at 34 days, all others at 28 days. The initial pH was adjusted with KOH. KCl was used to equalize the potassium content of acid and neutral media.

occurred more readily at pH 4 than at pH 7 but the ability of strain PRL 1598 to grow on acetate only at the higher pH value was a notable exception. *Claviceps* strain PRL 1980 was relatively fastidious and grew only with succinate or fumarate. Moreover, with succinate, no growth occurred at pH 7. When, after 22 days incubation, glucose was added to this medium and to other media on which strain PRL 1980 had failed to grow, a mycelium formed rapidly on all cultures except those containing acetate. Preparing the vegetative inoculum in a medium containing the carboxylic acid to be tested improved the growth rate but did not increase the number of permissible carbon sources.

Production of Alkaloids

Claviceps strain PRL 1980 produced ergot alkaloids on media containing citrate, α-ketoglutarate, succinate, fumarate, and malate but not acetate (Table II). The type of Krebs cycle acid present in the medium affected the yield, but the differences were modest. In cultures containing fumarate and malate, production may have been limited by high pH. Those with citrate remained acidic and attainment of maximum yield appears to have been delayed.

Table II. Effect of organic acids on alkaloid production (mg ℓ^{-1}) by *Claviceps* strain PRL 1980.*

Days	Succinate		Fumarate		Malate		α-Keto glutarate		Citrate	
	Alkaloid	pH	Alkaloid	pH	Alkaloid	pH	Alkaloid	pH	Alkaloid	pH
6	88 ± 5	7.4	102 ± 8	6.1	73±9	5.1	62 ± 7	6.2	34 ± 2	4.2
9	121±16	7.4	154 ± 4	7.6	179±6	7.4	178±13	6.8	112±13	4.6
12	226 ± 4	7.3	186±24	7.8	183±7	7.7	264±24	6.3	151±11	5.2

*Values are the mean and standard deviation for 3 flasks. Cultures, in 50 ml of medium 10-B-2 containing the appropriate organic acid, were shaken in 250-ml Erlenmeyer flasks at 24°C.

Uptake of Succinate

When mycelium from *Claviceps* strain PRL 1980 was incubated at 24°C in potassium phosphate buffer, pH 4.0, containing a low (0.83 mM) concentration of [2,3-^{14}C]succinic acid, radioactivity was taken up rapidly during the 20-minute observation period (Fig 1A). Measurements, after 15 minutes, of the distribution of radioactivity in the mycelium and effluent showed that only 0.1% of the total radioactivity entering the cells was oxidized to carbon dioxide. However, only 6% was recovered as succinate. If the [2,3-^{14}C]succinate had remained intact and in solution, the intra- and extracellular concentrations estimated from radioactivity would have been equalized during the first 3 minutes of incubation. Such a conclusion assumes that the factor of 4 ml g^{-1} dry weight used by Benko and coworkers to estimate the cell-water content of filamentous fungi applies to *Claviceps*. A similar though not identical value was adopted by Slayman and

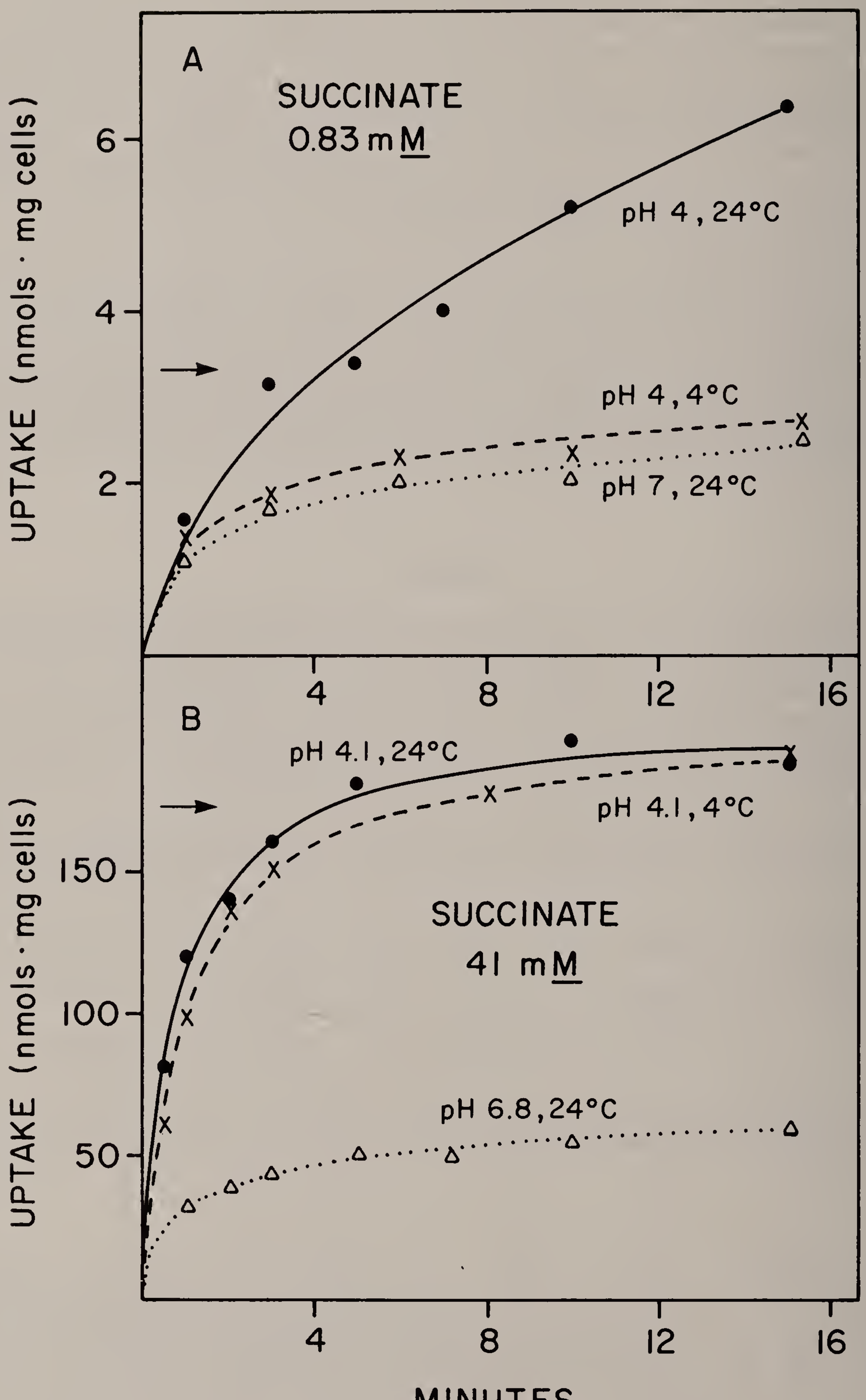

Fig 1. Effect of temperature and pH on the uptake of [2,3-^{14}C]succinic acid by *Claviceps* strain PRL 1980. Solutions were prepared as described in the text. Uptake was measured as the amount of radioactivity accumulated in the mycelium. The arrow indicates the amount needed to equalize the intra- and extracellular succinate concentrations. The uptake solution contained either 0.83 mM (panel A) or 42 mM succinate (panel B).

Slayman (1970) for *Neurospora crassa*. In contrast to the sustained uptake of labeled succinate observed at 24°C, incorporation of radioactivity at 4°C became very slow after the first minute. At the reduced rate of entry, it reached a value corresponding to balanced intracellular and extracellular succinate concentrations only after 30 minutes. A similar pattern was obtained at 24°C when the pH of the uptake solution was raised to 7.0.

When the concentration of [2,3-^{14}C]succinic acid in an uptake solution at pH 4.1 was increased to 41 mM, *Claviceps* strain PRL 1980 accumulated radioactivity rapidly at first but the rate declined as the intracellular and extracellular concentrations equalized (Fig 1B). This pattern was not changed substantially by lowering the temperature of the incubation mixture to 4°C. The value of Q_{10} at pH 4.1 was 0.5, substantially lower than the Q_{10} of 2 expected for a chemical reaction. Although not shown in Figure 1B, the rates of uptake at 24°C and 4°C were also very similar when the incubation mixture was at pH 7.0. As noted previously (Taber 1973), substantially less substrate entered at pH 7.0 than at pH 4.1. Ether extraction of cells incubated for 15 minutes at pH 4.1 and 24°C recovered 75% of the radioactivity; previous studies have shown this fraction to consist mainly of unchanged succinic acid (Taber 1973; 1976).

Results obtained in the earlier studies showed that, whereas phosphate could be omitted from the incubation mixture without altering the rate of succinate uptake, sodium and potassium ions affected the process. To detect a possible influx or efflux of these cations, a 41 mM succinic acid solution in water adjusted to pH 4.1 with KOH was incubated for 15 minutes with mycelium at 24°C. The cells took up 0.143 mmol of succinate and the content of potassium ions in the reaction solution decreased by 0.441 mmol. This represented an influx of approximately 3 mol K^+ accompanying each mole of succinate. The sodium content of the reaction mixture increased by 1.68×10^{-3} mol, an efflux too small to be significant. The pH of the solution increased from 4.09 to 4.18. Allowing for the buffering capacity of the succinate present, the equivalent loss of protons was 0.34 mmol, which corresponds to 2.3 mol of H^+ per mole of succinate taken up. In a control experiment lacking succinic acid there was a small loss of both potassium (3.8×10^{-2} mmol) and sodium (2.9×10^{-3} mmol), presumably due to leaching. Paper chromatographic examination of the uptake mixtures after incubation detected small amounts of mannitol in both the succinic acid and control solutions. The succinic acid solution, but not the control, also contained two amino acids. Their R_f values and color reactions matched those of glutamic acid and glutamine but their concentrations were too low to be significant.

Uptake of Other Krebs Cycle Acids by Claviceps Strain PRL 1980

Uptake of α-keto [5-^{14}C]glutaric acid at 24°C from a 41 mM solution at pH 4.0 was similar to that of succinate except that the amount of radioactivity in the mycelium declined rapidly after 4 to 6 minutes (Fig 2). At its maximum, the accumulated radioactivity was close to the value estimated to equalize the intra- and extracellular substrate concentrations. When the temperature of the uptake solution was reduced to 4°C, radioactivity accumulated in the mycelium at a similar rate but the subsequent decline was much slower. Shifting the pH of the uptake solution from 4.0 to 7.4 also changed the pattern of ^{14}C accumulation in the mycelium.

With 41 mM [2,3-^{14}C]fumaric acid at pH 4.1 and 24°C, the intracellular and extracellular concentrations of substrate were equalized over a similar time interval to that observed with succinic acid (Fig 3). Uptake continued beyond the equilibration point; the pattern resembled more closely that obtained with

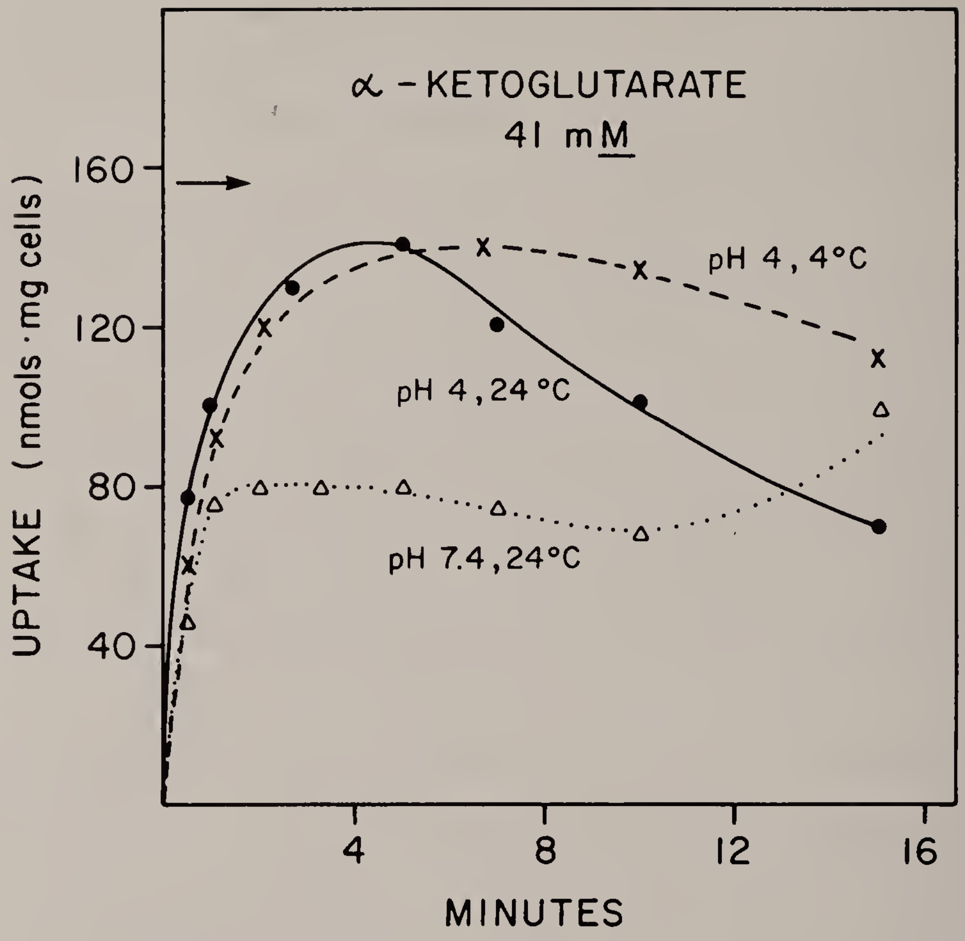

Fig 2. Effect of temperature and pH on the uptake of α-keto-[5-^{14}C]glutaric acid from a 41 mM solution. See Figure 1 and text for details.

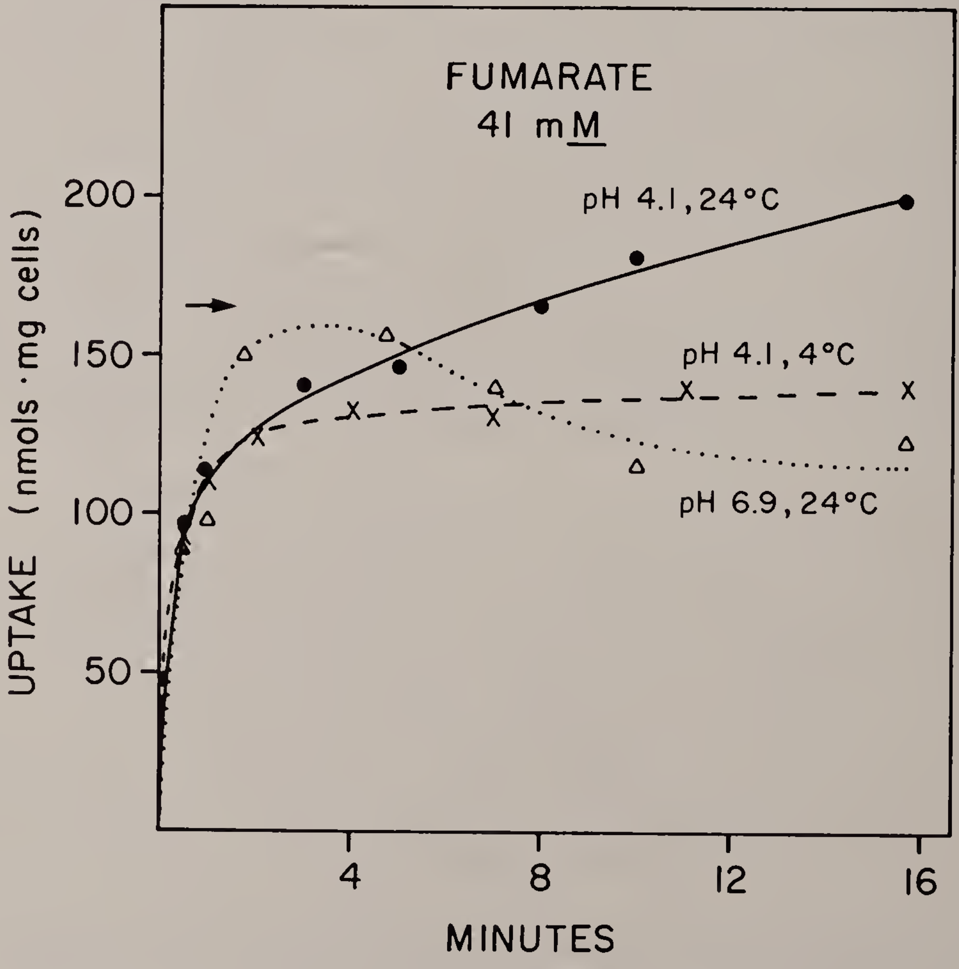

Fig 3. Effect of temperature and pH on the uptake of [2,3-^{14}C]fumaric acid from a 41 mM solution. See Figure 1 and text for details.

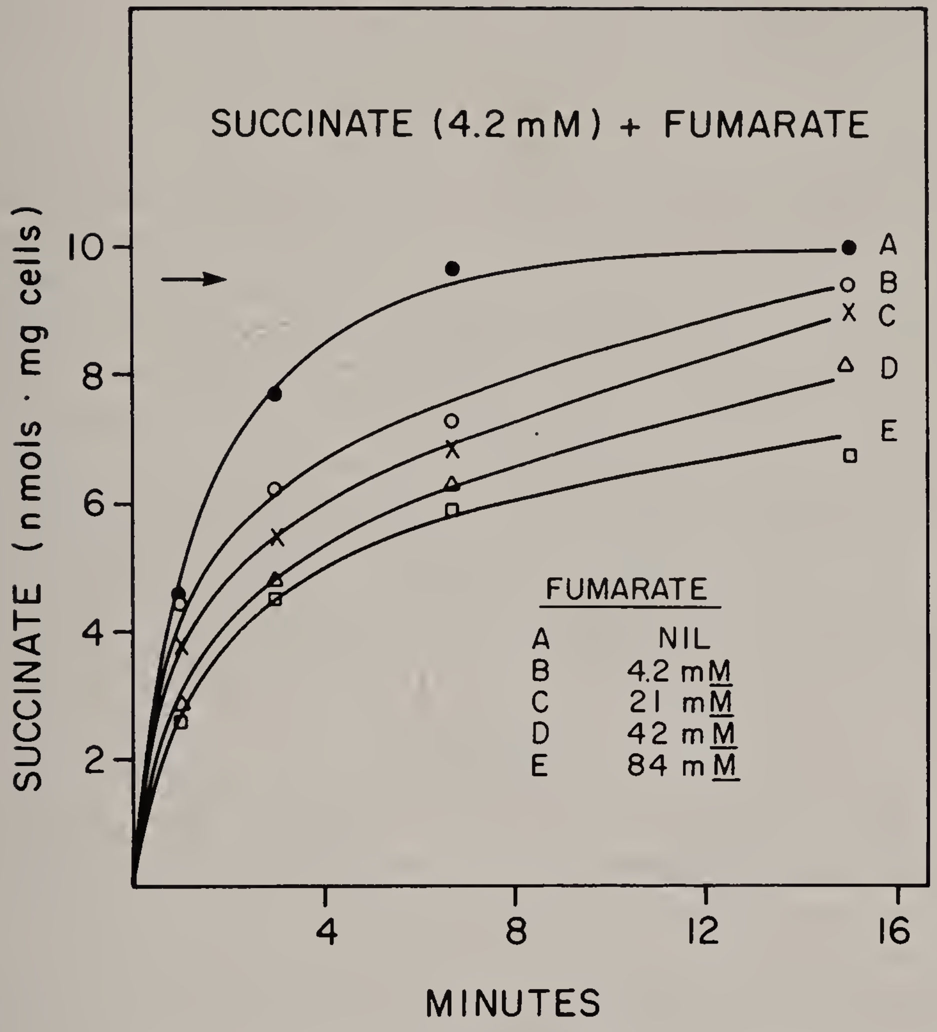

Fig 4. Uptake of succinic acid in the presence of various concentrations of unlabeled fumaric acid. The uptake solution contained 4.2 mM [2,3-^{14}C] succinic acid at pH 4.0. See Figure 1 and text for additional details.

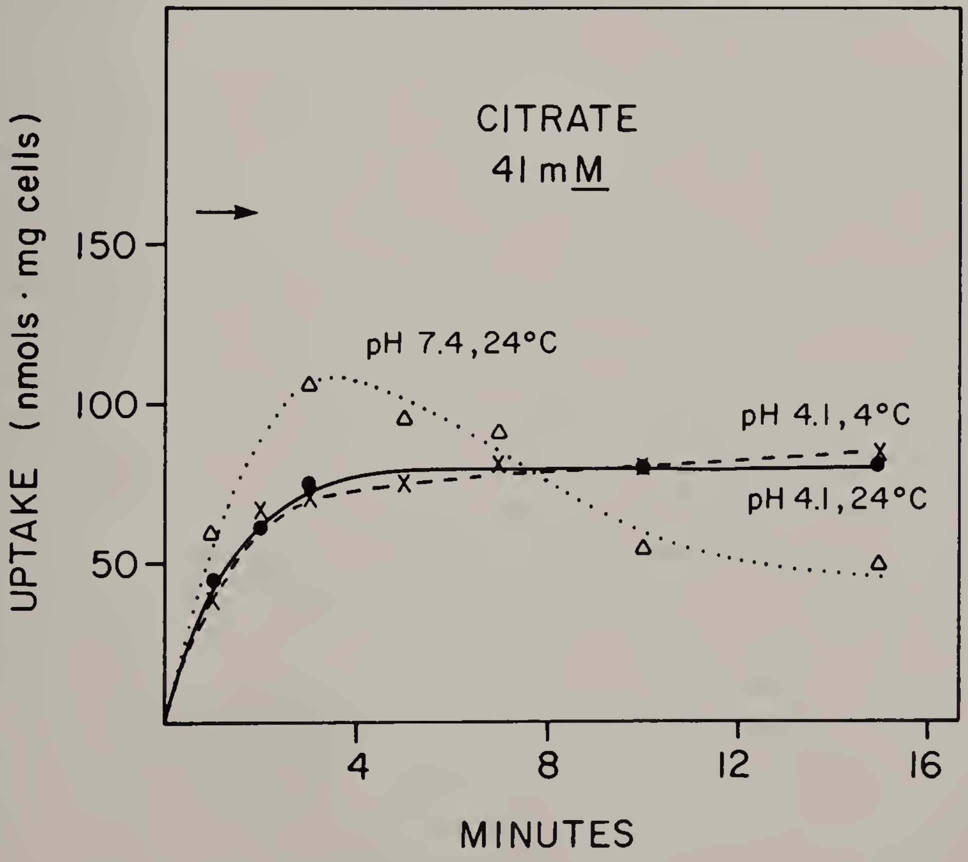

Fig 5. Effect of temperature and pH on the uptake of [1,5-^{14}C]citric acid from a 42 mM solution. See Figure 1 and text for details.

mycelium adapted to succinate (Taber 1971) than the one shown in Figure 2 where the cells had not previously been exposured to this substrate. Adding fumaric acid to an uptake mixture containing [2,3-^{14}C]succinic acid at 4.2 mM reduced the rate at which radioactivity was incorporated into the mycelium (Fig 4). However, the total accumulated radioactivity at each concentration of fumarate eventually approached a value corresponding to equal intracellular and extracellular concentrations. When the temperature of the uptake mixture containing [2,3-^{14}C]fumarate was reduced to 4°C, uptake beyond the initial phase was extremely slow and did not equalize the internal and external concentrations during the course of the experiment. A similar pattern was observed for the uptake of L-malic acid under all conditions of pH and temperature tested (data not shown) and for citric acid at both 4°C or 24°C when the uptake solution was at pH 4.1 (Fig 5). With fumarate and citrate, when the pH of the uptake solution was changed to 7.4, there was an unexpected increase in the rate of entry; the amount of radioactivity accumulated in the mycelium passed through a maximum after about 3 minutes, then declined. Apparently the substrate initially taken into the cells was being lost by efflux or metabolism.

Discussion

It is evident that *Claviceps* strains vary considerably in their ability to use carboxylic acids as the sole source of carbon for growth. Since *Claviceps* strains PRL 1980 and Ta 1 produce good yields of alkaloid whereas strains PRL 1565, 1578 and 1598 are poor producers, ability to assimilate the acids and ability to produce alkaloids are not closely linked. In media with mannitol as the main carbon source, *Claviceps* strain PRL 1980 produces alkaloids more abundantly if nitrogen is supplied as the ammonium salf of an organic acid than if an inorganic ammonium salt is used (Vining & Nair 1966; Brar et al. 1968). The results presented here indicate that the various Krebs cycle acids support comparable yields of alkaloid. Again, the response is not correlated with ability to serve as a sole carbon source for growth and uptake characteristics are not a determining factor.

Uptake studies with ^{14}C-labeled substrates indicated that the inability of *Claviceps* strain PRL 1980 to grow on citrate, α-ketoglutarate or malate cannot be attributed to substrate impermeability. At appropriate pH values, citrate, fumarate and α-ketoglutarate appeared to be metabolized. Since only acetate was toxic in this organism, the selective ability of succinate and fumarate to support growth might lie either in successful metabolic channeling of the substrate or in facilitated uptake allowing an adequate flow of carbon source into the cells. Earlier studies of succinate uptake demonstrated that it saturates at high substrate concentrations (Taber 1971) and is sensitive to sodium azide which, besides abolishing membrane proton gradients, also inhibits electron transport and thus impairs energy production (Harold 1972). Succinate uptake in *Claviceps* strain PRL 1980 differed from uptake of C_4-dicarboxylic acids in *Neurospora crassa* in being unaffected by the sulfhydryl inhibitor, iodoacetate (Wolfinbarger & Kay 1973). Also unlike *N. crassa* and bacteria, which metabolize Krebs cycle acids as fast as they enter the cell (Kay & Kornberg 1971; Lawford & Williams 1971; Fournier et al. 1972; Wilkerson & Eagon 1972), the *Claviceps* strain accumulated succinate within the mycelium (Taber 1973). However, high succinate concentrations were used in the *Claviceps* study. Under such conditions, if uptake outpaced metabolism of succinate, saturation of the rate of entry at high substrate levels would reflect the limiting rate of endogenous metabolic removal rather than saturation of a mediated transport system.

In the present investigation, *Claviceps* strain PRL 1980 mycelium exposed to a high concentration of [^{14}C]succinate accumulated radioactivity rapidly until the intracellular concentration approached that of the uptake solution. The rate after equalization was appreciably lower than has been observed with cells grown in a medium containing ammonium succinate (Taber 1976). This can be ascribed to reduced metabolic drag in mycelium not previously adapted to the substrate. When a low concentration of [^{14}C]succinate was used in the uptake solution, radioactivity accumulated in the mycelium, without change in rate, after the intracellular and extracellular concentrations had been equalized. Although little of the radioactivity was respired as carbon dioxide, only a small fraction could be recovered as unchanged succinic acid. This is consistent with an unmediated uptake process where the rate of entry associated with the lower external substrate concentration no longer exceeded the rate at which succinate was metabolized. In such circumstances, the decrease in metabolic rate expected at reduced temperature would also explain the different effects of temperature on uptake of succinate from dilute and concentrated solutions.

The evidence that uptake of Krebs cycle acids is insensitive to a large shift in temperature, except where metabolic drag is factor, excludes transport systems mediated by chemical reactions and implicates a diffusion process with a low energy of activation. Uptake from concentrated solutions can be driven at a high rate by the concentration gradient. However, movement of anionic species through the energized plasma membrane neutralizes the proton gradient, and a concurrent energy-dependent charge transfer is required to restore the membrane potential. The unequal exchange of sodium and potassium ions between the intra- and extracellular fluids during succinate uptake suggests that the monionic species is accompanied by a potassium ion. The magnitude of pH change is accounted for by the excess of potassium ions removed from the external solution.

The linear relationship observed between external concentration and uptake of Krebs cycle acids (Taber 1976) is accommodated by a diffusion mechanism with concomitant uptake of potassium contributing to the maintenance of electrical neutrality. Differences in uptake of these acids by *Claviceps* strain PRL 1980 may be due, at least in part, to differences in metabolic capability. Thus, failure to metabolize malate may prevent the generation of energy needed for cation transport and, indirectly, prevent equilibration of intracellular and external malate concentrations. Fumarate resembled succinate in its uptake pattern and it also decreased the rate of succinate uptake in competition experiments. Since the principal effect was to slow the approach towards equalization of cytoplasmic and external concentrations, altered cation transport due to metabolic changes may have been responsible. It is probably significant that succinate and fumarate, alone among the acids tested, were able to support growth of the organism as sole carbon sources.

The most plausible explanation at present for the beneficial effects of Krebs cycle acids on alkaloid production is that rapid diffusion of these substances into the mycelium builds up large intracellular pools which influence regulatory mechanisms in favor of secondary metabolism. Pazoutova and Rehacek (1981) have shown that access to citrate alters the levels of glycolytic and Krebs cycle enzymes in *Claviceps purpurea* strain 129 and influences differentiation of the mycelium. They suggest that this fungus may have included, in its adaptation to parasitic growth on grasses, a biochemical accommodation to the use of phloem sap rich in acids and amino acids related to Krebs cycle activity. Thus the pattern of growth, differentation, and secondary metabolism in media containing large amounts of carboxylic acids may simulate the natural condition for *Claviceps*.

Acknowledgement

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FIRST CANADIAN RECORD OF YELLOWFIN BASS, ANTHIAS NICHOLSI FIRTH, TAKEN OFF NOVA SCOTIA

An unusual red and yellow fish was caught by Japanese squid fishermen on the *Mikani Maru* using a semipelagic bobbin trawl at 190 m, at station 140 on the Scotian Shelf at 1355 h, 3 July 1980. We identify the species as the yellowfin bass, *Anthias nicholsi* Firth, (Fig 1) described from off Virginia. This is the first record of the species for Canada. The specimen is catalogued as Nova Scotia Museum No. NSM-980-120-1(1).

Neither Leim and Scott (1966) nor Legendre (1978) list *Anthias* for the Atlantic coast of Canada. Markle, Scott and Kohler (1980) list *Anthias* (?), based on a 21.5-mm larva from off Nova Scotia. Our record therefore confirms the presence of the genus and provides the first record of the species for Canadian waters.

The following account follows the format used in Leim and Scott (1966). *Anthias* is usually placed in the subfamily Anthiidae of the family Serranidae, for example by Heemstra (1973), although some authors such as Smith (1961) place it in its own family, Anthiidae. Disjunct lateral lines are used to characterize some serranoid families and subfamilies (Böhlke 1960) yet many species of *Anthias* possess and some lack continuous lateral lines. Whether, in *Anthias*, disjunct lateral lines are evidence of parallelism in or polyphyly of the genus, is unknown. Our counts and proportions are followed in parentheses by Firth's (1933) counts for the type specimens.

Yellowfin bass, *Anthias nicholsi* **Firth, 1933**
Barbier ligne-en-palier

Description

Body moderately elongate, deepest at level of pelvic fins, depth 2.6 (2.3) in standard length, caudal peduncle high. Head 2.7 (3.0) in standard length, blunt, profile steep; 3 opercular spines, preopercular serrated, spines enlarged at angle; mouth superior, angle oblique, upper jaw reaching just past mid-orbit. Inner teeth in jaws small, outer row enlarged, canines at front corners of jaws, those of lower jaw larger. Gill rakers 12 + 29 = 41 (8 + 27 = 35), long, length about 2/3 of orbit. Orbit 3.6 (3.3) in head length, about equal to snout length. Fins: dorsal (1), X, 14 (X,15) spinous and soft dorsal continuous, latter higher, spines provided with membranous flags, origin over pectoral base and insertion on caudal peduncle; caudal fin moderately forked; anal III,7 (III,7); first spine shorter than next 2 which are long, origin below soft dorsal; pectorals moderate, 17; most rays branched; length 1.2 (1.4) in head length; pelvics longer than pectorals, reach first soft anal ray, length 0.9 (0.9) in head length. Lateral line present, follows curve of back to an interruption just before caudal peduncle, continues on middle of side of caudal peduncle to caudal base; 22 + 7 = 29 (33) pored scales. Scales large, ciliated, covering body, sides and top of head. Vertebrae 26.

Coloration

Our specimen when received was yellow on the back, with a trace of red on some scales, becoming silvery yellow on the abdomen. Two dark yellow stripes on the sides of the head extend to the pectorals; 1 stripe below the eye extends

Fig 1. Yellowfin bass, *Anthias nicholsi*, captured by Japanese squid fishermen using a semipelagic bobbin trawl at 190 m, at station 140 on the Scotian Shelf (42°38′N, 64°41′W) at 1355 hrs., 3 July 1980. Neg. File No. 9536.

the entire length of the head, while the other begins just behind the eye. Fins are a darker yellow, with trailing edges of each fin red. This accords with Firth's (1933) type description, except there was a deep blue blotch in the middle of the back below the first dorsal spine; this in formalin turned olive. Also, there were 3 or 4 more-or-less well-defined lengthwise stripes on the body, although a trace of 1 yellow stripe above the lateral line remains in our specimen.

Distinctive Characters

Distinguished from other Canadian serranids by the large scales, moderately elongated body, large eyes and long pelvic fins. Distinguished from other fishes by the 3 opercular spines, large eyes, long pelvics and high interrupted lateral line.

Size

Our specimen, preserved, is 125 mm in standard and 163 mm in total length and weighs 64.8 g. Firth's (1933) type specimen was 150 mm in standard and 191 mm in total length.

Distribution

The yellowfin bass was described from a trawl catch east by south of Chesapeake Light Vessel and from 50 mi (80 km) east-half-north of Cape Henry, Virginia. Subsequently it was reported off Cape May, Ocean City, New Jersey (Fowler 1952). The Scotian Shelf specimen, probably a stray, extends the known range northwards more than 500 km. Canadian distribution: The present specimen was caught south of and between Baccaro and LaHave Banks off southeast Nova Scotia at 42°38′N, 64°41′W in 190 m.

Biology and Economics

The yellowfin bass is apparently a benthic shelf species inhabiting depths of 73 to 190 m. Its canine teeth suggest that it preys on small fishes or invertebrates. Nothing else appears to be known of its life history (Hardy 1978), except that a 21.5-mm larva doubtfully of this genus and species was caught 14 August 1976 on the Scotian Shelf (Markle et al. 1980). The species is not fished by commercial fishermen.

Discussion

Our specimen can be distinguished from the only other American species of *Anthias*, the crimson bass, *Anthias asperilinguis* Günther, by its 29 to 33 instead of 37 pored scales, lack of outer filamentous caudal fin rays and lack of teeth on the tongue.

Our specimen differs modestly from the types in some body proportions (body depth, head length, and orbit diameter) and in number of pored scales, 29 instead of 33, and more trenchantly in 41 instead of 35 gill rakers. Without additional specimens it seems unwise to emphasize these differences. The presence of flags on the dorsal spines of the Scotian Shelf specimen and their absence in the types may be due to differences in maturity or sex. Similar flags on the first dorsal spines are portrayed for *Anthias anthius* (Linnaeus) by Fowler (1936, Fig 341, from Lowe). It therefore appears wisest to identify our specimen with *Anthias nicholsi* Firth.

Acknowledgements

The fish was saved by Fisheries Officer, Peter Clark, an observer on board, and transmitted to the Nova Scotia Museum by Dr. Paul Odense, Halifax Laboratory, Department of Fisheries and Oceans. We are grateful to them for saving this new record for science. Jadwiga Aniskowicz made the radiograph. The photograph in Figure 1 is by Ron Merrick. We thank Vianney Legendre for coining the French common name and for comments on the manuscript.

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BY-LAWS
OF
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AS REVISED 1981

(Established in 1862 as an unincorporated Society and incorporated in 1890 by Chapter 123 of the Statutes of the Province of Nova Scotia).

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1. The name of the Society is the Nova Scotian Institute of Science.
2. The object of the Society is the promotion of scientific research and education by means of communication among persons interested in science through the holding of meetings and the publication of proceedings, reviews, and monographs.

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3. There shall be three classes of membership: ordinary, honorary, and institutional.
4. Any person interested in science is eligible for ordinary membership and shall become an active member upon payment of one year's dues to the Treasurer.
5. Any member distinguished in some branch of science or who has rendered conspicuous service to the advancement of science in Nova Scotia, or to the affairs of the Institute, is eligible for nomination and election as an honorary member. Nominations must be submitted to the Council in writing, be signed by three (3) members in good standing, and be accompanied by a document presenting the reasons for awarding the honor. Election of candidates shall require the support of a majority of Council members.
6. Any institution is eligible for institutional membership.

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7. Only ordinary and honorary members may vote or hold office.
8. Members of all classes will have the following rights and privileges:
   (a) to participate in any meeting of the Institute;
   (b) to submit papers for presentation to the Institute subject to paragraph 36 of these by-laws;
   (c) to submit papers for publication in the Proceedings subject to paragraph 37 of these by-laws;
   (d) to receive a copy of the Proceedings while in good standing.

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9. Honorary members shall not be required to pay a fee.
10. The annual fees for ordinary and institutional members shall be proposed by Council to the members, in writing, at least fourteen (14) days prior to the annual meeting for approval by a majority vote of the members present at the annual meeting. Annual fees, which will include payment for publications, shall be due and payable on the date of the annual meeting, or upon becoming a member.
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12. A member who is two (2) years in arrears in payment of his fees shall cease to be a member and his name shall be removed from the list of members.
13. Anyone who has ceased to be a member by reason of non-payment of fees may at the discretion of the Council be re-admitted as a member upon payment of the arrears or such amount thereof as the Council may decide.

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14. The officers of the Institute shall consist of a President, two Vice-Presidents, a Secretary, a Treasurer, an Editor, and a Librarian.
15. The officers, except the Librarian, shall be elected each year at the annual meeting of the Institute and shall hold office until the next annual meeting or until their successors are elected.
16. The Librarian shall be appointed annually by the elected members of Council and shall serve until a successor has been appointed.
17. The Council shall appoint a nominating committee consisting of three (3) ordinary members in good standing, at least two (2) weeks before the date of each annual meeting.
18. The nominating committee shall present in writing, at the annual meeting, nominations for:
    (a) officers (except the Librarian);
    (b) the other members of Council;
    (c) auditors;
    (d) nominees to government commissions.

    No member shall be nominated unless his consent has been received by the nominating committee.

    Further nominations for the officers and other members of the Council to be elected at the annual meeting may be made at the meeting by any two (2) ordinary members, but the consent of any member so nominated must have been obtained before he is nominated.

19. Election shall be by a show of hands unless a ballot is requested by an ordinary member.

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20. Officers shall, in addition to the performance of such duties as are incident to their office and of such duties as may be assigned to them from time to time by the Council, have the following duties and responsibilities:

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21. The President, or in his absence or inability to act, a Vice-President, shall preside at meetings of Council and of members and, subject to any direction of Council, be responsible for the general administration of the affairs of the Institute.

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22. The Secretary shall:
    (a) act as secretary and keep the minutes of meetings of members and Council;
    (b) prepare an annual report of the Institute;
    (c) issue notices of meetings of members and of Council;
    (d) deal with the correspondence of the Institute.

Treasurer

23. The Treasurer shall:
    (a) keep the records and receipts of all monies of the Institute;
    (b) ensure that all expenditures have been duly authorized and are evidenced by proper receipts and vouchers;
    (c) present to the annual meeting of the Institute an audited balance sheet and statements of income and expenditures;
    (d) bill members each year for the current year's fee and any arrears, and keep the Council informed of the status of members on their fees;
    (e) be responsible, under the direction of the Council, for the general management of the finances of the Institute.

Librarian

24. The Librarian shall:
    (a) prepare an annual report;
    (b) conduct the correspondence of the Institute arising from the mailing of the Proceedings;
    (c) keep the mailing list of the Proceedings up to date;
    (d) furnish the printers with the mailing list as required.

Editor

25. The Editor shall be responsible and have the authority for the editorial conduct of the printed Proceedings subject to the policy as determined by the Editorial Board and the Council.

Council

26. The Council of the Institute shall consist of the officers of the Institute and six (6) other members to be elected as provided by these by-laws at the annual meeting. Each Local Chapter shall be represented on Council by an additional member designated by the Chapter. If there are more than two (2) vacancies in the Council at any time, the Council may fill these vacancies and any person so appointed to fill a vacancy shall hold office until the next annual meeting.

27. The Council shall be responsible for the general management of the affairs of the Institute.

Meetings

Members

28. The annual meeting of the members of the Institute shall be held in the month of April in each year.
29. Other meetings of members shall be held at such time or times as the Council may determine, giving preference, so far as is practical, to the second Monday of each month from October to April both inclusive.
30. In addition to the consideration of matters relating to the management of the affairs of the Institute, the program of meetings shall consist of the presentation of original research, scientific demonstrations, lectures on scientific topics, or such other matters as the Council may determine from time to time.
31. Except as herein otherwise provided, members of all classes shall be given at least four (4) days notice in writing of meetings of members of the Institute. In special circumstances the Council may prescribe a shorter period in writing or otherwise.
32. Ten (10) ordinary members of the Institute shall constitute a quorum for meetings of members.

Council

33. Meetings of Council shall be held at such time as the Council may direct and, failing such direction, at such time or times as the President, or in his absence or inability to act, a Vice-President, may determine.

34. At least four (4) days notice in writing shall be given of meetings of the Council or, in special circumstances, a meeting may be called by shorter notice in writing or otherwise.
35. Five (5) members of the Council shall constitute a quorum for meetings of the Council.

Presentation of Papers

36. The executives of the Institute and the Chapters shall be responsible for formulating the programs for the regular monthly meetings, and for this purpose may delegate the responsibility for soliciting and receiving papers for presentation, accepting or rejecting submissions and arranging the programs.

Publications

37. The selection and publication of papers in the Proceedings and other publications of the Institute shall be the responsibility of an Editorial Board comprising the Editor, as Chairman, and four (4) other members appointed annually by Council.
38. The Editorial Board shall be responsible for establishing the policies and formats of the Institute's publications.

Finances

39. The Council shall be responsible for administration of the monies and funds of the Institute.

    The operation of the Society shall be carried on without purpose of gain for its members and any profits or other accretions to the Institute shall be used in promoting its objects.
40. The funds of the Institute shall be divided into:
    (a) Operational Fund
    (b) Publication Fund
    (c) Permanent Fund

    The funds shall be operated as separate entities and transfer of monies from one fund to another shall require approval of Council.

    Life membership fees, endowments, and bequests shall be placed in the Permanent Fund.

    All income received from the sale of the publications shall be deposited in the Publication Fund together with those monies received as grants or gifts that are designated for the support of publications, and that portion of the membership fees designated annually by Council for the support of publications.

    All other income including income from the Permanent Fund and the remainder of member and institutional fees shall be deposited in the operational account.
41. The Operational Fund, the Publication Fund and the Permanent Fund shall be kept in separate bank accounts in such bank or banks or in

investments as the Council may from time to time direct. Monies may only be withdrawn by cheques signed by at least two (2) officers of the Institute as determined by the Council.

42. Monies in the Permanent Fund, the Publication Fund, and the Operational Fund may be invested in such investments as the Council may determine, but only in investments that are authorized by the Trustee Act of Nova Scotia.

Local Chapters

43. Members of the Institute residing in areas outside the Halifax-Dartmouth region may apply in writing to Council for the privilege of establishing a Local Chapter. On approval, Council will arrange for the allocation to the Local Chapter of a portion of the annual dues of each member of the Institute registered as a member of the Local Chapter. Each Local Chapter shall elect its own officers, and arrange its own meetings and activities in conformity with the objectives and by-laws of the Institute. Each Chapter shall designate its own representative to Council.

Amendments

44. The by-laws may be amended by the affirmative vote of two-thirds of the ordinary members present and voting at an annual or special meeting of the Institute provided that notice of such meeting containing the nature of the proposed amendment or amendments is mailed to all ordinary members at least fourteen (14) days prior to the meeting.
45. The Council may at any time authorize the calling of a meeting of members to consider proposed amendments to the by-laws, and on receipt of a requisition in writing signed by at least ten (10) ordinary members of the Institute and containing proposed amendments, it shall direct their calling of a meeting of members for the consideration of such amendments.

PROCEEDINGS OF MEETINGS

1980-81

HALIFAX CHAPTER

1st Extraordinary Meeting, 28 Oct. 1980
"Food, Energy and the Environment". Fourth A.C. Neish Memorial Lecture. D. Pimentel, Cornell University.

2nd Extraordinary Meeting, 7 Apr. 1981
"Introduction of Exotic Species of Seaweeds in Northern European Waters: The *Macrocystis* Example". G.T. Boalch, Marine Biological Association of the United Kingdom.

1st Ordinary Meeting, 2 Oct. 1980
"Bird Navigation". B. Moore, Dalhousie University.

2nd Ordinary Meeting, 3 Nov. 1980
"Kelp Growth in the High Arctic". A.R.O. Chapman, Dalhousie University.

3rd Ordinary Meeting, 1 Dec. 1980
"Geology by Remote Sensing". W. Bruce, Canada Centre for Remote Sensing, Ottawa.

4th Ordinary Meeting, 5 Jan. 1981
"Petroleum Geology of the Eastern Seaboard". A. Grant, Bedford Institute of Oceanography.

5th Ordinary Meeting, 2 Feb. 1981
"Acid Rain". Panel Discussion: W. Watt, Resource Development Branch; D. O'Neil, Atmospheric Environment Service; P. LeBlanc, Nova Scotia Power Corporation; P. Hinch, Nova Scotia Department of the Environment.

6th Ordinary Meeting, 2 Mar. 1981
"The Microelectronic Revolution: Running Wild!" B. Paton, Dalhousie University.

7th Ordinary Meeting, 4 May 1981 (jointly with the Valley Chapter, at Dalhousie University)
"Dinosaurs—Were They Warm-Blooded?" H.B.S. Cooke, Dalhousie University.

VALLEY CHAPTER

1st Ordinary Meeting, 10 Nov. 1980
"Kelp Growth in the High Arctic". A.R.O. Chapman, Dalhousie University.

2nd Ordinary Meeting, 2 Dec. 1980
"Surveillance by Satellites". W. Bruce, Canada Centre for Remote Sensing, Ottawa, and G. Stevens, Acadia University.

3rd Ordinary Meeting, 12 Jan. 1981
"Petroleum Geology of the Eastern Seaboard". A. Grant, Bedford Institute of Oceanography.

4th Ordinary Meeting, 10 Feb. 1981
"Shad in the Bay of Fundy; the Fish and the Fishery". M. Dadswell, Fisheries and Oceans, St. Andrews, N.B.

5th Ordinary Meeting, 7 Apr. 1981
"Thunderstorms, Ozone, Smog and Kinetics". J.M. Roscoe, Acadia University.

6th Ordinary Meeting, 4 May 1981 (jointly with the Halifax Chapter, at Dalhousie University)
"Dinosaurs—Were They Warm-Blooded?" H.B.S. Cooke, Dalhousie University.

7th Ordinary Meeting, 25 May 1981
"The Biology of the Bay of Fundy". G.R. Daborn, Acadia University.

THE PRESIDENT'S REPORT

Institutions usually survive only as long as they meet the needs of their constituency so, in the 119 years of its existence, the Nova Scotian Institute of Science must have served its members well. During the past year the Institute continued its policy of providing a forum for scientific discussion of topical issues in a broad range of subjects. A series of excellent speakers brought us up to date on the scope of the microelectronic revolution, on the applications of remote sensing by satellite and on the prospects of major petroleum discoveries in our coastal waters. We were given fresh insights into bird navigation and into the growth of seaweed in high arctic waters. A panel of scientists directly invovled in monitoring "acid rain" and evaluating its consequences presented a many-sided view of this current threat to our environment while a concerned biologist from England alerted us to the risks associated with cultivating giant kelp outside its natural habitat.

Again this year we were fortunate in being able to join with the A.C. Neish Memorial Trust in co-sponsoring a lecture by a scientist of international renown. Dr. David Pimentel offered a challenging view of the dilemmas now facing mankind on the issues of "Food, Energy and the Environment". We are particularly pleased that his lecture was presented at the Nova Scotia Agricultural College and formed part of their 75th Anniversary year observances. On a second occasion we enjoyed a congenial association with a fellow institution through joint sponsorship with the Halifax Field Naturalists Society of the lecture by Dr. Bruce Moore on "Bird Navigation".

This year the Valley Chapter has again had an active programme. Many of the topics in our lecture series have been presented both in Halifax and in Wolfville but Valley members also had opportunities to learn about shad in the Bay of Fundy and the kinetics of thunderstorms. The contributions of our speakers will be acknowledged in due course by a complete listing of the Halifax and Valley Chapter programmes in the PROCEEDINGS but I would like now to express an extra measure of appreciation for their help. I would like, too, to thank those who assisted in many ways to arrange the programme and express our gratitude to the institutions that provided us free of charge, with lecture rooms and other facilities for our meetings.

The publishing activities of the Institute have continued in 1980-81 at the accelerated level established in recent years through the vigorous editorship of Dr. J. McLachlan and his associates. With financial assistance from the Natural Sciences and Engineering Research Council, and the Government of Nova Scotia and with the strong support of institutions such as the Nova Scotia Museum, the National Research Council of Canada and Dalhousie University, it seems reasonable to expect that the PROCEEDINGS has resumed its role as an appropriate medium for publications of regional importance. We can take considerable pride in this achievement at a time when many journals are finding it increasingly difficult to keep afloat.

This year has presented the Institute with no formidable problems, either financial or organizational. This is, to a large extent, a result of the skill and devotion with which the Officers and Council of the Institute have carried out their responsibilities. I would like to thank all of them for their hard work and for their cheerful acquiescence whenever I have asked for help or advice. Their cooperation and support has made my term of office exceedingly pleasant.

L.C. Vining

INSTRUCTIONS TO AUTHORS

The *Proceedings of the Nova Scotian Institute of Science* publishes the proceedings of the Institute and original articles, including notes, pertaining to the natural sciences of the Atlantic Provinces, especially in biology and geology. Manuscripts may be either in English or French, and acceptance for publication is based on recommendations of referees.

Manuscripts should be typewritten, double-spaced on white paper 21.5 by 28 cm (8.5 by 11 in) with margins of 4 cm (1.5 in). Underline only material to be set in italics, and use capital letters only when letter or words should appear in capitals in the printed paper. Layout and style should follow that used in this volume. The original copy and one duplicate are required. Each page of the manuscript should be numbered, the first page carrying only the title, authors' names and affiliations, and any necessary footnotes.

Spelling should follow that of **Webster's Third New International Dictionary**, and authors are responsible for consistency in spelling.

Abbreviations, nomenclature, and symbols for units of measurements should follow international recommendations. Metric units, SI units and decimals should be used whenever possible. Use day/month/year sequence for dates. Do not use periods after such abbreviations as "mm, kg, DOE, NRC, etc."

Taxonomic keys should be in aligned-couplet form in zoology and paleontology, and in multi-level indent form in botany. Synonomy in botany, zoology, and paleontology should be in the short form—taxon, author, year, page—with full citation in the references.

An abstract of not more than 200 words should precede the body of the text. This should be followed by an introduction, methods, results or observations, discussion, and references. In some cases a combination of these sections may be more effective.

References should be checked with the original article and referred to in the text by author and date, in parentheses. References should be listed alphabetically at the end of the manuscript. Reference to papers in periodicals must include author, date, title, journal, volume number, and inclusive pagination. Serials are abbreviated in the form given in **Bibliographic Guide for Editors and Authors** (the American Chemical Society, 1974). For serials not found therein, the abbreviated name in the **World List of Scientific Periodicals** (Butterworths, 1963) is used. The following are examples of style for references from journals, books, and symposium volumes:

Author, A.N. and Other, T.H.E. 1978. Title of the article. *Name of Journal,* (Volume) 99: 1-10. (Omit word volume)

Author, A.N. and Coauthor, A. 1978. *Full Title of Book.* Publisher, City.

Author, A. 1978. Title of Article. In *Title of Book or Symposium Volume.* (ed. J. Smith and B. Jones). Publisher, City, pp. 256-301.

Tables should be numbered with roman numerals, having a brief title, and referred to in the text. Vertical rules should not be used. Tables must be typed separately from the text on individual pages.

Originals of illustrations should not be more than three times the size of the final reproduction, 11 by 18 cm. Figures, including those in plates, are numbered consecutively in arabic numerals, and each referred to in the text. Original drawings, and one set of clean copy, are required and should be made with india ink on white paper. All lines must be sufficiently thick to reproduce well, and letters and characters sufficiently large to be legible and not less than 1 mm high when reduced. Captions for illustrations should be typed separately from the text.

Photographs should be mounted on heavy bristol board, and ready for reproduction. Prints must be of high quality on glossy paper with no space between those mounted in groups. Photographs of poor quality will be rejected and this, in turn, may require extensive revamping of the ms.

Color illustrations will be accepted at the discretion of the Editor. However, the cost of color reproduction is borne by the authors who must submit a statement accepting this responsibility.

Authors are responsible for editing the alley proof. Orders for reprints, in addition to the 15 supplied gratis, must be received when the gally proof is returned.

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1981-82

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